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EXTRAPLEURAL PNEUMOTHORAX

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EXTRAPLEURAL pneumothorax is not a new procedure. Tuffier performed the operation for the first time in 1891, and in 1910 he reported three cases in which the pneumothorax had been maintained by refills of air. J. B. Murphy, in his oration on chest surgery at the annual meeting of the American Medical Association, in 1898, referred to extrapleural pneumothorax, thoracoplasty, and intrapleural pneumothorax as the three methods of collapsing a tuberculous lesion of the lung. He reported a case of extrapleural apicolysis performed upon a patient "too ill for drainage of the tuberculous cavity," with a successful clinical result and apparent healing of a large cavity, but made no mention of refills. Murphy referred to Tuffier's use of the procedure as a preliminary to radical excision of a tuberculous lesion from the upper lobe. In 1913 Tuffier's attention turned to fat as a filling medium, but in the same year Mayer published the x-ray pictures of a patient in whom the whole of the parietal pleura was stripped from the chest wall and diaphragm and a total extrapleural pneumothorax obtained. Rieckenberg reported two cases in 1920; Romanis and Riviere performed an extensive extrapleural pneumonolysis in 1923, but no attempt to refill the space with air was made till the twelfth postoperative day, when the lung had re-expanded and obliterated the space. In 1932, six cases were reported by Jachia and twelve by Sebestyen, who advocated the operation as an adjunct to intrapleural pneumothorax to avoid the dangers of intrapleural pneumonolysis and obtained nine satisfactory results. In 1935 cases were reported by Monaldi (15), and by Nissen, and Zorini

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described his "apicolysis simplex," in which no refills were given but the space allowed to fill up with serum, thus maintaining the collapse for a few weeks only. Michelsson described a similar operation.

Graf deserves the credit for the recent revival of interest in this procedure. Disturbed by the incidence of basal complications following upper thoracoplasty, he turned his attention to extrapleural pneumothorax in 1934 and reported a series of 107 cases in 1937. Schmidt adopted the operation later than Graf and reported seventy-two cases in 1936 but has recently extended his series to 155 cases. Both Graf and Schmidt have reported favorably on the results obtained up to the present time. A. Maurer and his associates have performed the operation upon forty-three patients, and O. Monod reports a series of forty cases from the Hôpital Laënnec in Paris.

Extrapleural pneumothorax was introduced at the Brompton Chest Hospital to help a large group of patients for whom no other form of collapse therapy appeared to be indicated; early unstable cases too acute for thoracoplasty, with intrapleural pneumothorax impossible, and late cases with lesions too widespread, or general condition too poor, to warrant a thoracoplasty.

The attitude of the physicians and surgeons at the Brompton Hospital to the indications for thoracoplasty has been rather more conservative than in this country. Apicolysis with plombage was abandoned for two reasons: first, the high incidence of perforation of the wax into the lung or through the chest wall; second, the low incidence of cavity closure revealed after absorption of the effusion which forms around the wax. Phrenicectomy had failed to produce results sufficiently impressive to outweigh the disadvantage of a paralyzed diaphragm, should apical thoracoplasty be indicated later. Temporary phrenic nerve interruption by crushing was open to the same criticism, as the paralysis remained permanent in a high percentage of cases. Thus, with intrapleural pneumothorax technically possible and satisfactory in less than one-half of the cases on which it was attempted, and with thoracoplasty at the other end of the scale, its use restricted by fairly rigid indications, the need for further methods of collapse therapy became imperative.

The first extrapleural pneumonolysis at the Brompton Hospital was performed by Roberts early in 1937. The patient was a girl, aged 25 years, with large cavities in both upper lobes, infiltration in the remaining zones, and severe toxemia. An extrapleural pneumothorax was established on the left side, with surprisingly little postoperative reaction. The night sweats ceased abruptly, the temperature came down, the sputum diminished to 1 oz. The patient died six months later with extensive abdominal tuberculosis, but the extrapleural pneumothorax had shown no signs of obliteration, despite infrequent refills, and a cavity 11 cm. by 6 cm. had been completely collapsed.

Encouraged by the technical success of the operation in closing this large cavity in a very sick patient, with little operative upset and only a moderate reduction in vital capacity, other patients with bilateral disease were subjected to the procedure. The operation was extended to early cases with unstable types of disease, patients in whom an intrapleural pneumothorax had been attempted and failed, and the results were encouraging.

INDICATIONS

On the basis of the experience gained with this series, an attempt, such as the following, was made to formulate the indications for the operation:

1. If it was decided that collapse therapy was indicated in a certain case, pneumothorax selected as the method of choice and attempted without success, then extrapleural pneumothorax logically appeared to be the next step, in cases unsuitable for thoracoplasty.

2. In cases with a basal intrapleural pneumothorax and contraselective collapse, with cavities held open at the apex by extensive adhesions, it was considered safer to abandon the pneumothorax and replace it by an extrapleural pneumothorax, rather than embark upon a hazardous attempt to cauterize or enucleate the adhesions thoracoscopically. If the presence of middle or lower lobe lesions rendered the maintenance of the basal collapse imperative, then an extrapleural could be performed above the intrapleural pneumothorax, and a communication between the two established thoracoscopically as soon as the extrapleural pneumothorax had become stabilized.

3. In certain cases in which a thoracoplasty appeared to be indicated by the type of lesion, but where there existed some doubt as to the ability of the patient to withstand the more traumatizing procedure on account of asthma, emphysema, poor respiratory function due to costal rigidity, or threatened postoperative complications due to a paralyzed diaphragm, it appeared justifiable to perform an extrapleural pneumothorax as a preliminary measure to be followed by the rib resection as soon as the cavity was collapsed and the sputum diminished. The pneumothorax could be abandoned if the patient was unable to tolerate the collapse.

4. In a different class was the case in which thoracoplasty was contraindicated by the extent of the disease, the presence of bilateral cavities, a recent spread of acute exudative disease, the poor general condition of the patient or his low vital capacity, and in those cases it was considered justifiable to perform a unilateral or bilateral extrapleural pneumothorax in an attempt to improve the condition of the patient sufficiently to render possible a thoracoplasty at a later date.

The contraindications are as little understood as the indications at present. Roberts has always maintained that the operation should not be performed upon any patient suitable for thoracoplasty. There are no

clinical methods of predicting before operation whether it will be possible to complete the apicolysis; and trial alone can solve this point. The operation can be abandoned at any stage, as no irrevocable damage is done.

The following are brief reports of five of Roberts' patients, representing different types of lesion and the response to extrapleural pneumothorax.

THE TECHNIQUE OF THE OPERATION

Before describing the technique employed by Roberts, I shall mention certain anatomic characteristics of the extrapleural plane. Over the greater portion of its surface the parietal pleural is attached to the endothoracic fascia by loose, easily disrupted, connective tissue. The plane is traversed by numerous small blood vessels passing from the chest wall to the pleura. Hovelaque, Monod, and Evrard, in their excellent monograph on the anatomy of the thorax, have described zones of close adhesion between the parietal pleura and the thoracic cage. Anteriorly the pleura is adherent to the posterior surfaces of the costal cartilages and sternum. A costopleural ligament in the region of the second costal cartilage has been described by Amon-Jean. Posteriorly a vertical band of adhesions overlies the costovertebral articulations, sending prolongations laterally along the necks of the ribs and medially onto the bodies of the vertebrae and disks, as far anteriorly as the azygos veins. In the normal chest there are no dense adhesions over the dome of the pleura or down its mediastinal aspect till the arch of the aorta and the azygos major vein are reached.

Any doubts concerning the existence of an endothoracic fascia will soon be dispelled during the performance of this operation. It is very easy to wander out into the plane between the endothoracic fascia and the chest wall while stripping upward over the dome. The intercostal nerves, especially the second, have a great tendency to adhere to the fascia and to be stripped down with it, and the difficulty thereby encountered is usually the first indication that the wrong tissue plane has been entered. Occasionally the plane between the pleura and the fascia will be obliterated by pathologic adhesions; the apicolysis may then be completed successfully in the plane between the fascia and the chest wall.

Local anesthesia is satisfactory, but general anesthesia was employed in this series for three reasons: first, positive pressure may be required, should the pleura be torn and the whole lung collapsed in a patient with low vital capacity; second, the operation is in a dangerous area, and it may be necessary to enlarge the approach at a moment's notice to control a large bleeding vessel; third, it is essential that the trachea and bronchi be kept clear of secretions during the operation by repeated aspiration through a rubber catheter. Both cyclopropane and nitrous oxide-oxygen-ether have proved satisfactory on account of

the high oxygen concentrations, the quietness of the respiration, and the absence of coughing. Preoperative medication is reduced to a minimum consistent with a quiet induction.

The patient is placed in the lateral position, and the arm held forward by a nurse or placed palm uppermost against the patient's chest. An oblique incision is made along the fourth rib, centering over its angle. The muscles are divided in the line of the skin incision, and 2 to 3 inches of the fourth rib are resected subperiosteally back to, but not including, the transverse process. In identifying the extrapleural plane the tendency is to go too far and perforate the pleura in the belief that it is the periosteum of the rib bed. The plane is developed with the finger, and the apicolysis continued under direct vision, using an illuminated retractor to hold down the lung. The pleura is stripped with a metal spatula, a gauze sponge on a holder, a pair of long curved scissors or a pair of Hartmann forceps carrying cotton pledgets. Hemostasis is obtained by diathermy coagulation, temporary gauze tamponade, or the application of silver dura clips close to the chest wall prior to division of the vessels. In closing the defect in the chest wall, approximation of the intercostal bundles is facilitated by incising the attachment of the external intercostal muscles to the ribs above and below, as suggested by Churchill, or by elevating the periosteum and attached muscles from the lower and upper borders of these ribs respectively, as suggested by Hautefeuille and Dreyfus-Le Foyer. The serratus posterior superior muscle may be employed as a patch to reinforce the suture line. An airtight closure is essential. Either catgut or silk sutures may be employed, depending upon the personal preference of the operator.

There is a great temptation in performing this operation to do too little. In two or three of the early cases the extent of the pneumonolysis was insufficient, and the cavities were not completely collapsed. In one of these cases it has recently been proved possible to extend the pneumonolysis sufficiently to collapse the cavity by resecting a portion of the sixth rib and stripping upwards and forwards till the original extrapleural space has been entered, and then proceeding in the usual way till sufficient collapse has been obtained.

It has been observed that the double layer of pleura forming the floor of the space tends to contract during the first few weeks and straighten out between its mediastinal and parietal attachments; the final extent of the pneumothorax, therefore, will depend upon the position of these attachments.

For an upper lobe lesion the pleura was stripped to the level of the seventh or eighth rib posteriorly, the third or fourth rib anteriorly, to a level below the line joining these two points laterally. It is very important to free the lung from the costal cartilages, anteriorly, and the paravertebral sulcus, posteriorly, and down the mediastinum to the level of the aortic arch or azygos major vein. Only by freeing the upper lobe

on all its aspects could a true concentric relaxation be obtained. If the lesion involved the greater portion of the lung, the pleura was stripped down to the level of the diaphragm.

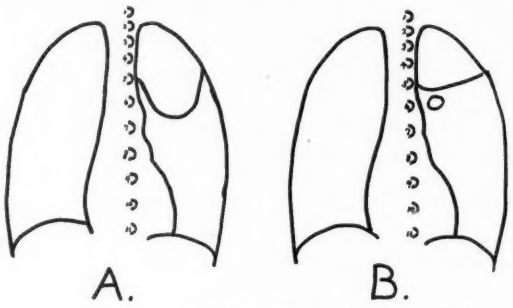

Fig. 1.—An extrapleural pneumonolysis, apparently adequate at the time of the operation (*A*), may prove to be too limited in extent to collapse an upper lobe lesion when the inevitable contraction of the pleural floor of the pneumothorax has occurred (*B*).

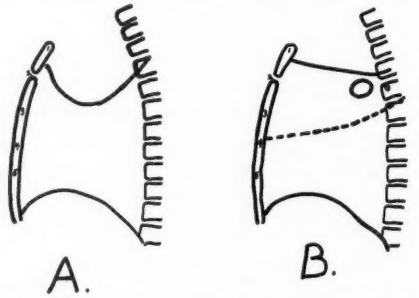

Fig. 2.—Inadequate pneumonolysis: lateral view, *A* before and *B* after contraction of the pleura. To maintain collapse of the upper lobe the parietal pleura should have been stripped down to the level represented by the dotted line in *B*.

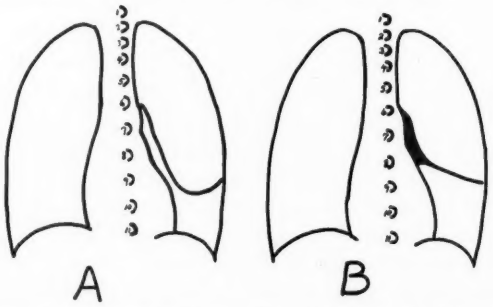

Fig. 3.—Adequate extrapleural selective pneumothorax. The point of reflection of the parietal pleura from the chest wall and mediastinum determines the final extent of the pneumothorax. Appearance immediately following operation (*A*); after contraction of the pleura (*B*).

In the Brompton series the first refill was given on the day of the operation, to diminish the risk of losing the pneumothorax should the

air be forced out by the straining efforts of the patient while regaining consciousness. A second refill was given the next day, and then at intervals increasing a day at a time. A positive pressure of 10 to 20 cm. of water was maintained. Refills were originally given posteriorly through the space where the rib had been resected, but in the later cases, in which the pleura was stripped down further anteriorly, the refills were given in the first interspace in the midclavicular line.

The frequency of refilling is controlled by the rate of air absorption, and an attempt is made to maintain a constant positive pressure. A rapid swing of the pressures to the negative side is an indication for more frequent refills, to prevent any concertina action in the cavity. In an established pneumothorax it is usually sufficient to give refills at two- or three-weekly intervals.

Perfect asepsis is essential in the management of these cases, and, ideally, all refills and aspirations should be performed by an assistant present at the operation, who has had the opportunity to observe for himself the position of the lung and pleural reflections in relation to the chest wall.

At the Brompton Hospital collapsing operations have always been regarded as merely incidental in the therapeutic program, auxiliary to the cardinal principle of rest therapy. All patients were kept on strict bed rest for four to six weeks following the pneumonolysis, and then returned to the sanatorium for a six months' period of graduated rest and exercise.

COMPLICATIONS

The pleura was punctured on two occasions during the operation: in one, the hole was small, easily closed with a small free graft of muscle tissue, and produced no deleterious effects; in the other case the hole was too large to close, and a basal pneumothorax was obtained. I shall refer to this case again. The effects of opening the pleura depend upon the vital capacity of the patient and his ability to tolerate a total collapse of the lung until air can be aspirated from the basal intrapleural pneumothorax.

Hemorrhage from small blood vessels was encountered while stripping the pleura and controlled by diathermy coagulation or temporary gauze packing. Damage to the structures of the mediastinum was not encountered but constitutes a serious danger. In any case in which the presence of dense adhesions increased the risk of damage to the lung or perforation of the cavity it was always considered wiser to abandon the operation.

Minimal operative shock and very little postoperative reaction were observed. Subcutaneous emphysema usually developed during the first twenty-four hours but was seldom more severe than following

thoracoscopy. Slight mediastinal emphysema occurred in one case but disappeared in forty-eight hours; three patients complained of transient discomfort on swallowing.

A serosanguineous effusion developed in every case. In the majority it was small and was absorbed spontaneously during the first few weeks. In a few cases the effusion was large and was aspirated, while in two cases it recurred following aspiration. The management of the effusion remains problematical. Its presence may serve a useful purpose in keeping down the lung, but it was considered safer to aspirate large effusions to diminish the risk of infection, especially if there had been hemorrhage into the space. It was our impression that in those patients, if left alone, a thick layer of fibrin was deposited on the walls of the space, and its subsequent organization increased the tendency of the space to obliterate. Aspirations were performed in the axilla through the space above the level of the pleural reflection, with the patient inclined toward the affected side. In four patients there was a delayed hemorrhage into the space. In one patient the blood was aspirated, but an effusion recurred. There appeared to be a slow continuous oozing of blood into the space. In two patients the blood could not be completely aspirated, owing to coagulation: one filled up with fibrin but the collapse was maintained; the other became infected with streptococci and staphylococci of low virulence, six weeks after the operation, and the space was drained. Nevertheless, the general condition of this patient was improved by the collapse of the tuberculous lesion, and a thoracoplasty will be performed at a later date to close the extrapleural space. In the fourth patient the hemorrhage was fatal. When coagulation renders aspiration through a needle impossible, it is justifiable to insert a thoracoscopy cannula into the space and aspirate through a rubber catheter.

Reference has already been made to the single patient that became infected; there was no instance of tuberculous infection of the space up to the time when these cases were reviewed in November.

Ballooning of the cavity due to kinking of the bronchus may occur, but if the air pressure in the extrapleural pneumothorax is maintained at a level constantly more positive than the intrabronchial air pressure throughout the whole respiratory cycle, the cavity will gradually collapse by absorption of the contained air.

Two patients died, probably because of errors in technique in both instances. The first was an advanced case with bilateral disease and a 5 cm. cavity in the left upper lobe. A hole was torn in the pleura, too large to close, and the whole lung collapsed. The extrapleural space was packed with gauze to control oozing, and the wound closed. Two days later the gauze was removed under a second general anesthesia. The patient developed a fulminating nontuberculous bronchopneumonia

in the opposite lung and died. In the second patient, also an advanced case, a hemorrhage of 2½ pints of blood occurred into the extrapleural space forty-eight hours after the operation, and the patient died before a transfusion could be administered. It was thought that a large vessel had been damaged by the diathermy, and a slough had separated from its wall.

There was no instance of atelectasis of the lower lobe, although the diaphragm was paralyzed in many of the patients, in contrast to the high incidence of basal atelectasis following upper thoracoplasty. This may be due to the fact that the mechanics of the chest are but slightly impaired, paradoxical movements in the diseased lung cease when the chest is closed, and the power of expelling secretions by coughing is retained. The notable absence of bronchial stasis in the functioning lower lobe is one of the more attractive features of this procedure. The average reduction in vital capacity was 25 per cent of the preoperative value. Gaubatz, working on respiratory function in Schmidt's clinic, concluded that the reduction was only half that caused by a selective upper thoracoplasty producing a similar degree of collapse. There was no instance of spread of the tuberculous disease to the opposite lung, but this complication may occur on account of the rapidity with which the collapse is produced.

Of late complications I am not entitled to speak, as our experience is too brief. The future of the operation will depend upon the incidence of infection, which on general principles should be higher than in intrapleural pneumothorax, and secondly, upon the tendency to obliterate before the lesion has had time to heal; but so far our observations lend no support to the suggestion that this will prove a serious disadvantage, as it seems probable that in many instances the operation will constitute a first step in a delayed thoracoplasty.

I shall summarize briefly a series of about thirty-three operations performed by Roberts up to the end of 1937. The figures given must be regarded as approximate only, as the series will be reported in detail in the April issue of the British Journal of Tuberculosis.

There were ten early cases among patients for whom intrapleural pneumothorax was unsuccessful. The disease was bilateral in nine. The cavity was collapsed in every case, all patients were improved clinically, and the sputum had become negative in seven. There were no complications in this group.

Of about eighteen advanced cases, seven patients had bilateral cavities; in three, the other lung was collapsed by intrapleural pneumothorax, and in two patients the whole of one lung was involved. A bilateral extrapleural pneumothorax was performed successfully in one case.

Fourteen patients were improved, and the cavity appeared to be collapsed in nine. The two fatalities and all the complications occurred in this group.

In two cases dense adhesions prevented the lung from being stripped down completely on the mediastinal aspect, but an extensive lateral pneumonolysis allowed the lung to relax in against the mediastinum. In three patients the operation was abandoned on account of dense adhesions between the pleura, endothoracic fascia, and chest wall.

Churchill has performed the operation in seven cases at the Massachusetts General Hospital. In six the cavity has apparently been collapsed. There were no deaths. In two cases a sterile serosanguineous effusion recurred following aspiration, which had to be repeated. In one patient a very acute tuberculous infection of the extrapleural space occurred, with rapid formation of thick pus containing tubercle bacilli: but there was no evidence of a bronchial fistula or secondary infection.

Combining the two series of Roberts and Churchill, totaling 40 cases, the following figures are revealed: 12 early cases among patients for whom intrapleural pneumothorax had failed—cavity closed and clinical condition improved in all patients. Twenty-eight advanced cases unsuitable for thoracoplasty—2 deaths; 3 cases, operation abandoned; 23 cases, extrapleural pneumothorax established and maintained; 17 improved clinically; 13 cavity closed.

I shall refer briefly to the experience of other clinics. Graf operates under local anesthesia and drains the space for the first 24 to 48 hours by means of a rubber catheter inserted into the wound and attached to an apparatus which maintains a constant atmospheric pressure. He reports 107 cases, of which the majority have been converted to oleothorax, and the longest maintained for two and one-half years. There were 7 deaths from infection, all occurring among the first 48 cases; since then the technique has been modified. Schmidt also operates under local anesthesia, with the patient in the sitting posture, and closes without drainage. He replaces the air by sterile paraffin only in those cases showing a tendency to obliterate. In his latest published series there are 155 cases, of which 124, or 80 per cent were satisfactory. In 66 per cent of the cases the space remained dry, the remainder requiring aspiration; postoperative hemorrhage occurred into the space in 13 cases, but did not jeopardize the final results. Oil was introduced in a third of the cases. Secondary infection was mentioned, but its incidence not stated. There were 14 deaths, 2 due to the operation, 9 to progression of the disease in spite of good collapse, and 3 following thoracoplasty performed upon 7 patients in whom a satisfactory extrapleural pneumothorax could not be induced and, therefore, hardly attributable to the

latter procedure. Both Schmidt and Graf state that thoracoplasty is simplified by a preliminary extrapleural pneumothorax.

We can draw the following conclusions concerning this procedure:

1. Extrapleural pneumothorax is a method of obtaining selective and effective concentric relaxation of the lung.

2. The operation is associated with moderate shock and postoperative reaction, and can be performed upon poor risk patients.

3. The best results so far obtained have been in early cases among patients for whom intrapleural pneumothorax had failed. The collapse of large cavities, and the reduction in toxemia and the quantity of sputum have led to sufficient improvement, in certain acute and advanced chronic bilateral cases, to warrant consideration of thoracoplasty at a later date.

4. Neither the operations nor the postoperative management are simple procedures.

Our attitude at present must be tempered with extreme caution, and the determination not to be misled into unwarranted optimism by satisfactory early results. Judgment must be reserved till we know more about the severity of the late complications. The operation is still purely experimental and must not be rashly seized upon as a panacea for any and every form of the disease. We do suggest, however, that sufficient evidence is now at our disposal to justify a further clinical trial.

In closing I wish to acknowledge my gratitude to Mr. Roberts and Dr. Churchill for permission to refer to their cases, and to express my regret that Mr. Roberts was unable to attend this meeting and present his reports personally.

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DISCUSSION

DR. EDWARD D. CHURCHILL, Boston, Mass.—I will not attempt to add anything to the presentation by Mr. Belsey. I think he has covered the subject very adequately and with full conservatism.

I may say that I have had a recent letter from Mr. Roberts, who still holds the point of view portrayed by Mr. Belsey. I also discussed the matter this winter with Professor Nissen, of Istanbul, who has had an extensive experience with this operation and, I think, holds views about the same as those presented by Mr. Belsey.

Both Mr. Roberts and Professor Nissen have called attention to what I am certain will happen in this country, and that is an unwarranted extension of indications for the use of extrapleural pneumothorax and an unwarranted optimism about the results which are going to be obtained. Nissen said that on the Continent it is being popularized and used in place of thoracoplasty, and Mr. Roberts referred also to the tendency in England, particularly on the part of interns, to seize upon this procedure as possibly a substitution for thoracoplasty. Both of them feel, and I feel also from my very limited experience, that the procedure, if we include the late complications of maintaining refills, is a more dangerous procedure than thoracoplasty and that the late complications must be reckoned with. I should not want extrapleural pneumothorax to be presented to this audience as a substitute for thoracoplasty but rather as a more dangerous procedure to be used in cases in which thoracoplasty and other methods of treatment cannot be applied.

DR. JOHN C. JONES, Los Angeles, Calif.—We have had, in all, forty-one cases of extrapleural pneumothorax, and Dr. Skillen at Olive View Sanatorium is now in the process of checking twenty-five operations on twenty-three patients in that institution, two of the patients having had bilateral extrapleural pneumothorax.

I believe we should designate this operation as a surgical extrapleural pneumothorax, in contradistinction to the medical extrapleural pneumothorax described in the European literature by Rotta, Le Fevre, and Gau, where saline solution injected under pressure has been followed by air refills in order to dissect out the extrapleural space.

Our results with this type of surgery (surgical extrapleural pneumothorax), although the cases are very recent, have been beyond all expectations. In the twenty-five operations that Dr. Skillen recently reviewed there was but one complication that was serious, and that was a pure tuberculous infection of the extrapleural space, controlled by aspiration and needle irrigation with saline solution. It is an operation that can be performed on young individuals—one of our patients was 11 years old and another 15 years of age, so that it does open up a field for collapse therapy in a large group of patients in the second decade, for whom we consider thoracoplasty only in the exceptional individual. The same applies to the group who are too old for thoracoplasty.

There is this point, just as Dr. Churchill has brought out, that is, the operation no doubt will be abused. Already, by way of the grapevine, it has gone through the sanatorium that there is an operation that has completely replaced thoracoplasty. That, of course, is not true. Only in one patient have we done an extrapleural pneumothorax when we chose to do a thoracoplasty, but in that individual it was from absolute refusal to accept surgery other than this operation.

There are one or two points about the technique. In practically all of our cases, after the pleurolysis, we have instilled 200 to 300 c.c. of saline solution into the space before closure. It seems to facilitate finding the space postoperatively; it may be that the weight and the volume of the fluid maintains a larger space than the air alone, and if the patient requires aspiration postoperatively, it is easier to aspirate bloody fluid if saline solution has been instilled at the time of the operation.

There is one other point about technique. If careful dissection of the serratus posticus superior muscle is done, a neat repair will result in an almost airtight cavity so that at the time of the complete closure one can see ballooning out and sucking in of this muscular flap with respiration. The instrument we have used for illumination and retraction is a one-half inch flexible blade Cameron Retractolite, which of course has been on the market for several years.

DR. RICHARD H. OVERHOLT, Brookline, Mass.—I think it is fortunate for all of us that Mr. Belsey has been here to present this subject so completely and so convincingly, and we should thank him and also Mr. Roberts for introducing this procedure to the English-speaking countries.

Last year we were confronted with the problem of collapse treatment in a very severe case of asthma. Intrapleural pneumothorax had failed, and bilateral thoracoplasty seemed out of the question because of the difficulty of maintaining the collapse in asthmatic patients even after a satisfactory thoracoplasty. We also did not want to interfere with the thoracic cage or diaphragmatic movement. We thought wax filling would inadequately collapse the cavities. We recommended an extrapleural pneumothorax, but it was not until October that permission was granted for this operation.

At that time Mr. Tubbs, who had been working with Mr. Roberts at St. Bartholomew's Hospital in London, came over to work with us. Fortified by his first-hand knowledge of this operation, we proceeded with our first case at that time. We have since performed the operation thirty-one times in twenty-six patients. We feel that it will have a definite place in collapse treatment of tuberculosis but that its place will be limited mostly to the extensive bilateral cases and those less extensive cases in which the disease is too active to manage by thoracoplasty.

It is my impression from the x-ray films shown by Mr. Belsey that we are selecting for this operation cases with even more far-advanced disease that those of Mr. Roberts. Based on the x-ray appearance alone we would have recommended thoracoplasty in possibly 50 per cent of the cases he has shown.

MR. O. S. TUBBS, London, England.—Dr. Overholt has already mentioned the fact that in all these patients we felt thoracoplasty was contraindicated. He mentioned a patient who had asthma since childhood and in whom we thought thoracoplasty was inadvisable.

(Slide) The picture on the left shows the x-ray of that patient who had asthma, and you can see the cavities on both sides. The second picture shows the x-ray appearance after the operation which was carried out on both sides. You will see on the right-hand side that the operation had not been extended down sufficiently far, and there was still a persistent cavity. The patient's sputum remained positive.

Dr. Overholt then resected a rib lower down, the fifth rib, and stripped the lung down further; the appearance after the second operation on the right side, in October, can be seen. The third operation was performed in November. Since then the patient has improved clinically and has remained sputum-negative.

(Slide) We have divided the thirty-one patients into three groups, thoracoplasty being contraindicated in the first group due to some concomitant disease. The first x-ray picture was a representative of that group, that of the patient with asthma.

The second group, containing eighteen patients, included those with marked activity and febrile disease. Such a case is the one on the left, and you see that the patient had cavitation extending over the upper half of each side. This is the present x-ray after bilateral pneumothorax, and that patient is clinically improved but still has a positive sputum. We feel we stripped down the left side insufficiently far. There is more than one persistent cavity on the left side, accounting for the positive sputum.

(Slide) This is another case representing the active group, a girl aged twenty-two years, who had a left intrapleural pneumothorax, and on the right side, an extrapleural pneumothorax. It shows persistence of the cavity. The operation was performed only three weeks ago.

(Slide) This is the third group. Eight of the twenty-eight patients fall into this group, those with extensive lesions which, although fibrotic, would require a long and hazardous program if treated by thoracoplasty. The picture on the left shows the x-ray which, if treated by thoracoplasty, would probably require an upper six rib on either side. That on the right shows the appearance of a bilateral extrapleural pneumothorax. The patient has improved.

(Slide) This is the last x-ray, another, of the extensive group. This girl had a large intrapleural pneumothorax on the left side, but we could not get the lung to expand by reducing the intrapleural pressure on that side. If such could have been accomplished, it would have enabled us to do a right upper thoracoplasty. We felt that with the left lung so extensively collapsed, thoracoplasty would be too dangerous. Therefore, we did an extrapleural pneumothorax of the right side. The patient is improved and has a negative sputum. What the outcome will be is impossible to predict. Those are the three types of patients that we select: the complicated cases, those with active disease, and those with extensive bilateral disease. As Dr. Churchill, Dr. Belsey, Dr. Jones, and Dr. Overholt all said, the operation will probably not replace thoracoplasty. We have limited the use to cases in which thoracoplasty would have almost certainly ended in the death of the patient.

DR. POL N. CORYLLOS, New York, N. Y.—First there is a point of Greek grammar. It seems that on this side of the Atlantic we are more careful with Greek grammar than on the other side. We say *pneumonolysis* and not *pneumolysis* because we mean lysis of the lung. It is natural that I try to preserve the grammar of my ancestors from a rough handling in my adopted country. Moreover extrapleural pneumothorax is not a pneumonolysis; it is a pleurolysis because we do not free the lung from the pleura; we free the parietal pleura from the chest wall.

Personally so far I have performed extrapleural pneumothoraces on eleven patients only. In one patient the lung was so hard and fibrotic that although the pleura was separated from the chest wall the lung resisted collapse. This patient later had thoracoplasty.

The technical part of the procedure does not present any special difficulties. Stripping of the parietal pleura is occasionally difficult at the apex and the head of the ribs. Once the pleura is freed from these points, its separation from the chest wall and the mediastinum does not present any special difficulties.

Regarding the indications for this procedure I agree with Drs. Belsey, Churchill, and Overholt; they must be limited to the cases in which thoracoplasty is indicated, but it cannot be advised because of the general condition of the patient, of limited vital capacity, contralateral basal lesion, and other causes already mentioned by the essayists and discussers. The principal indications will be found, I believe, in bilateral cases.

In the case reported by Dr. Belsey, in which purulent exudate had developed in the extrapleural space, I would not exclude the presence of bronchial fistula. If I

have understood correctly, gas analysis of the air contained in the extrapleural space showed 4.3 per cent of oxygen; my experience with tuberculous empyema has taught me that when oxygen is above 1.0 per cent a bronchial fistula should be suspected.

Regarding postoperative complications I was particularly fortunate with my cases. There was no postoperative shock of any importance nor hemorrhage or infection. So far I have not used any ligatures or clips. I have only taken the precaution at the end of the operation to pack tightly the extrapleural space for a few minutes with dry gauze using for that purpose a head roll.

The airtight closure of the wound is facilitated by previous dissection of the mass of the paravertebral muscles between the second and sixth interspaces and their retraction mesially from the transverse processes. At the end of the operation this muscle flap can be applied on the posterior end of the opening which is the most difficult to close, forming an excellent covering for it.

I shall say a word about a question which troubles me. So far, why have we been unable to maintain patent the extrapleural space created by the old procedure of apicolysis, with refills of air, and were obliged to use, since Tuffier and Baer, all kinds of foreign material in order to maintain the collapse of the apex? In other words, what is the cause of the success of Graf and Schmidt in maintaining extrapleural pneumothorax? I am not satisfied with the explanation that subfascial stripping of the pleura has anything to do with it. After all the endothoracic fascia like the subperitoneal fascia are simply layers of connective tissue interposed between the pleura and the intercostal muscles and periosteum of the ribs. It is not possible to distinguish an external and an internal surface in this layer. Stripping of the pleura takes place in the thickness of this areolar tissue. I believe that the success of Graf is simply due to the very extensive pleurolysis performed by this author. In fact, in apicolysis we all endeavored to limit the stripping of the pleura to the apex and to avoid the creation of spaces larger than 500 to 700 c.c., in order to prevent sliding of the paste downward and to limit the weight of the paste. I believe, therefore, that the realization of extrapleural pneumothorax is due to very extensive pleurolysis.

In my series of eleven cases all these operations had been performed under local anesthesia. The incision was 12 cm. long and parallel to the spinal border of the scapula at equal distance from it and the posterior middle line. The trapezius and rhomboid muscles were sectioned, and 12 cm. of the third rib were resected from its transverse apophyses. Stripping was carried on with sponges soaked in novocain, 1 per cent, with adrenalin; retraction and lighting of the space was done with a long Cameron light. There was very little pain, if any, during the stripping of the pleura, and this was completely absent when I used sponges soaked with novocain. In no case was tearing of the pleura or of the lung produced.

Although it is too early to express an opinion on this procedure, I think that we should use it as a method of exception and should refrain, at least at the present, from unwarranted enthusiasm.

DR. H. F. NEWTON, Boston, Mass.—It would look, from the color of this discussion, as though Mr. Belsey perhaps infected us with a virus of enthusiasm for this particular procedure when he came to Boston last fall. I agree with him and also with Dr. Churchill, that this operation is no substitute for thoracoplasty; but following his direction, largely, and operating upon thirteen patients during the fall and winter, I had one rather interesting experience that I think is worthy of brief enumeration.

It has already been emphasized by the author and the discussers that in a chronic fibroid case where the pleurae are absolutely adherent and no extrapleural space is surgically demonstrable the operation must be abandoned. There is, how-

ever, the opposite extreme which I experienced once in these thirteen cases. We attempted this procedure in a young woman, 22 years of age, with a very recent infection of about four to six months and bilateral disease with cavitation in one lung. She was obviously sick and running a fever, but was maintaining her weight and general condition so that it seemed as if some operation might be done, at least without too much risk.

In trying to separate the pleura from the endothoracic fascia, I was struck in not finding, as in all the other acute cases which I had personally handled, that the space was as freely dissectable as has been outlined by some of the men here. We ran into marked adherences and lymph spaces in which one could find at least half a teaspoonful of white fluid, and this lymph collection with acute edema and gluing of the tissue was indeed very much more pronounced along the mediastinal side, so that when dissection had reached the apex, I felt it not wise to go further.

Possibly this experience had some latent bearing on what was said this morning as to lymphatic infection and possibly tuberculous empyema. I would like to ask Mr. Belsey if they have seen anything similar to this. I have been rather struck that it was the only case of my thirteen (and they were all acute bilateral cases) in which I had this particular experience.

I would like to add that the patient did not develop tuberculous infection of the extrapleural space. I fully expected she would. Cultures of the fluid and the exudate from the extrapleural pneumothorax have not shown tubercle bacilli, but I feel it is somewhat analogous to the case of Dr. Churchill's, which proved to be tuberculous infection of the extrapleural space postoperative.

MR. RONALD BELSEY, London, England.—There is just one point on the question of gas analysis. I want to show again the slide where I gave the analysis of the gas. I think the percentage of oxygen was not much higher than 1 per cent, and the percentage of carbon dioxide was 12 per cent. Dye was injected in that case and did not appear in the sputum.

DR. CORYLLOS.—Still, 1.05 is too high after infection. One-tenth of one per cent!

MR. BELSEY.—With regard to Dr. Newton's question, we have not observed the lymphedema of the extrapleural plane, and in Dr. Churchill's case, in which tuberculous empyema subsequently occurred, we did not notice any collection of lymph outside of the pleura at the time of operation.

That is all I have to add, except to reiterate my remarks concerning the purely experimental nature of the procedure and warning you not to expect too much from it.

EXTRAPLEURAL PNEUMOTHORAX IN THE TREATMENT OF PULMONARY TUBERCULOSIS*

A Preliminary Report

Richard H. Overholt, M.D., Boston, Mass., and
Oswald S. Tubbs, F.R.C.S., London, England

EXTRAPLEURAL pneumothorax is the term applied to a form of collapse therapy in which the parietal pleura is stripped from the chest wall by a surgical operation, thereby creating a space into which air can be introduced and the collapse maintained. After its creation, this form of pneumothorax differs from the usual intrapleural pneumothorax in that the collapsed part of the lung is covered by the parietal as well as the visceral pleura. It is directly comparable to the collapse produced by extrapleural pneumonolysis with plombage except that air is used for filling the artificially created space instead of paraffin wax or living tissue, such as muscle or fat. The advantages of air over these solid fillings are: (1) The extent of the collapse may be controlled to a certain degree after closure of the wound by either injection or withdrawal of air. (2) A more extensive collapse may be obtained, as large amounts of air do not tend to perforate the lung or gravitate toward the diaphragm as do similar amounts of wax. Failure to close cavities by plombage is usually attributable to a limited and insufficient separation of the pleura from the chest wall; the surgeon realizes that an extensive separation would require more wax than can be safely used. (3) Air has less tendency to produce a local reaction than a solid foreign body, such as wax. (4) Experience has shown that wax, even in small amounts, may at some later time perforate into the lung.

Extrapleural pneumothorax is not a newly conceived means of collapse, for Tuffier[1] treated a patient in this way in 1910. Mayer,[2] Jessen,[3] and Nissen[4] subsequently reported short series of cases, but it was not until Graf's report[5, 6] in 1936 that serious attention was given to the procedure. Graf drained the extrapleural space with a rubber catheter during the immediate postoperative period; this procedure sometimes resulted in infection. Schmidt[7] adopted the principle of Graf's operation but used no drainage. He published very encouraging results in a preliminary report on seventy-two patients. Roberts,[8] in England, following Schmidt's technique, introduced this measure to the English-speaking countries. One of us (O.S.T.) was associated with this work, and it was felt that the early results were sufficiently hopeful to justify a further trial of the method.

*Read (by title) at the Twenty-First Annual Meeting of the American Association for Thoracic Surgery at Atlanta, Ga., April 4, 5, and 6, 1938.

The first of our series of thirty-one operations (three of twenty-eight patients had bilateral operations) was performed in October, 1937. Our experience, therefore, is too recent to draw definite conclusions as to the type of case to which extrapleural pneumothorax is best suited. Up to the present we have selected only those patients for whom any other form of collapse therapy offered no hope of a successful outcome. We wish to stress that we consider extrapleural pneumothorax is not a form of collapse therapy introduced to replace the modern selective thoracoplasty but is an alternative measure when the latter is contraindicated. In all the cases intrapleural pneumothorax had been attempted and had resulted either in failure of induction or, if successfully induced, in contraselective collapse due to indivisible adhesions.

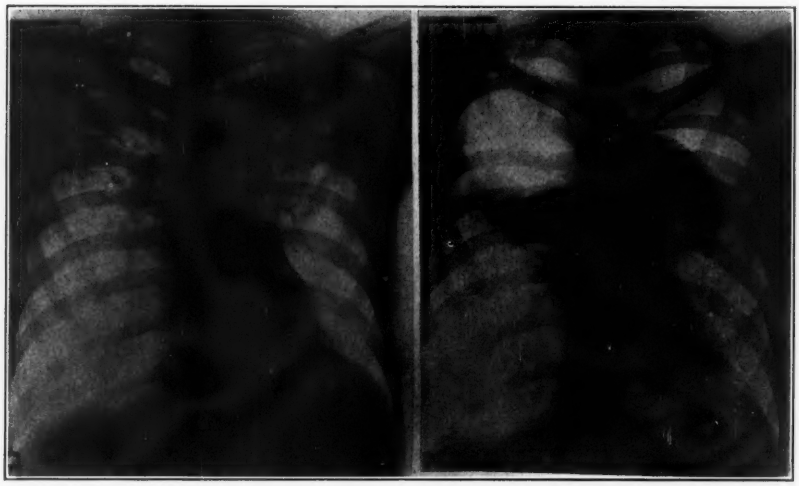

Fig. 1.—J. McG., 26-year-old man, had an extensive exudative and cavernous lesion in the upper half of each lung (*A*). He was thin, febrile, and looked ill. Examination showed: blood pressure, 85/55; blood picture, very active type; sedimentation rate, 53 mm. in one hour. Crushing of the left phrenic nerve in May, 1937, caused no improvement, and the hemidiaphragm was still paralyzed in December, 1937. Extrapleural pneumonolysis for pneumothorax treatment was performed on the right on Dec. 21, 1937, and on the left on Feb. 25, 1938. He has since showed marked clinical improvement, but the sputum is still positive from a residual cavity on the left side (*B*) resulting from insufficient pneumonolysis.

Hemidiaphragmatic paralysis had failed or, in our opinion, would have given insufficient relaxation to heal the lesion, or was contraindicated on the grounds of an extensive bilateral involvement and dyspnea.

The factors which rendered the patient unsuitable for thoracoplasty may be divided into three groups:

1. *Lesions Too Active.*—Evidence of too great activity to justify thoracoplasty has been deemed to exist in the presence of one or more of the following signs: toxic appearance, fever, rapid sedimentation

rate, white blood corpuscle count favoring marked activity, serial radiograms showing extension of an exudative lesion with cavitation. This type of active lesion has been seen most frequently in young patients in the first half of the third decade or late teens, in whom the ordinary intrapleural pneumothorax was urgently required but had been found impossible. Extrapleural pneumothorax now offers these patients an alternative method of collapse. Eighteen of the twenty-eight patients fall into this group. The radiograms of two patients belonging to this group are reproduced in Figs. 1 and 2, showing the appearance before and after the induction of an extrapleural pneumothorax.

2. *Patients with extensive bilateral lesions* of a fibrocavernous nature are unsuitable for bilateral selective upper thoracoplasty because such treatment would necessitate a long and hazardous program. Extra-

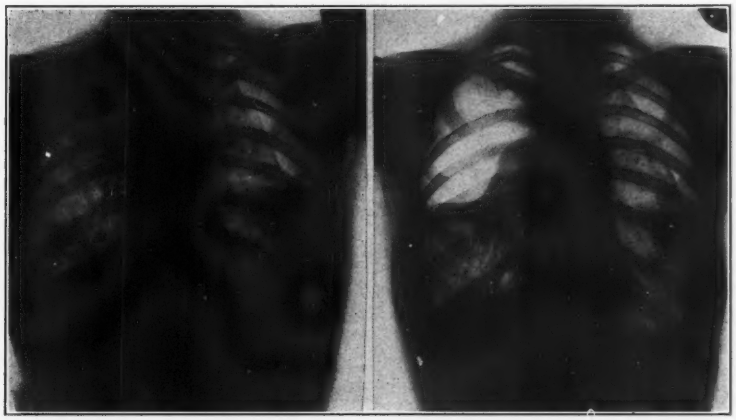

Fig. 2.—D. DeC., 22-year-old girl, had an active bilateral lesion partially controlled on the left side by an intrapleural pneumothorax (*A*). Three years' sanatorium treatment had failed to prevent progression on the right side, and the patient had lost 13 pounds in weight during this time. *B*, a radiogram taken on March 10, 1938, shows good selective collapse obtained by right extrapleural pneumonolysis performed on Feb. 16, 1938. All the cavities have not yet closed but should do so with maintenance of the pneumothorax treatment.

pleural pneumothorax is ideal for such patients, as its two greatest merits are the absolute selectivity of the collapse with preservation of all healthy lung tissue (Figs. 1-4) and the minimal disturbance caused by the operation. Eight of the patients fall into this group. In four of these, one side had already been treated by an upper thoracoplasty. In another, the more recent and less extensive side has been treated by extrapleural pneumothorax with the intention of treating the other side by thoracoplasty later, if the patient shows sufficient improvement. One patient showed a bilateral upper zone lesion which would have necessitated an upper six rib thoracoplasty on each side; he has been treated with bilateral extrapleural pneumothorax with apparent success (Fig. 3). Another patient presented rather a different problem: she

had an almost total pneumothorax on the left, and re-expansion had not been obtainable by reducing the pressures. A selective thoracoplasty on an upper zone lesion on the right carried too great a risk of interference with respiration in the lower lobe to justify operation. An extrapleural pneumothorax on this side caused minimal disturbance and has rendered the sputum negative (Fig. 4). The remaining patient

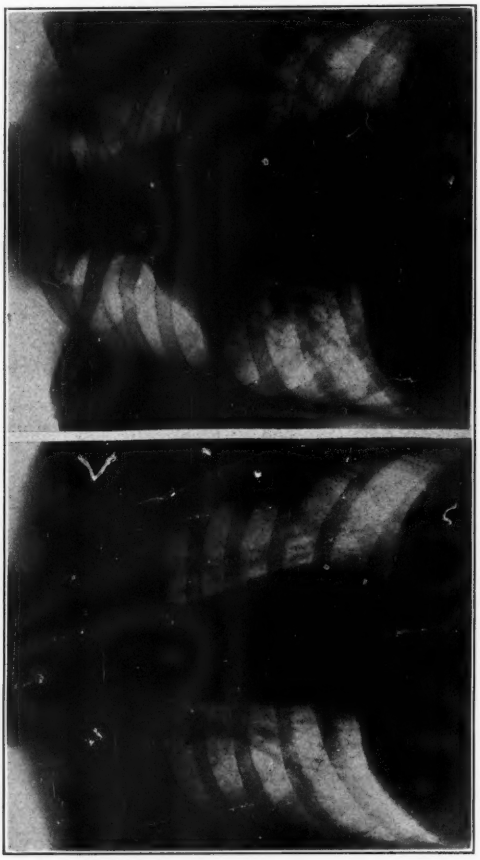

Fig. 3.—H. H., man aged 45 years, had bilateral fibrocavernous disease limited to the upper third of each lung (4). The sputum was positive. Extrapleural pneumonolysis for pneumothorax treatment was performed on the right on Jan. 27, 1933, and on the left on March 9, 1933. The sputum is now negative. The x-ray appearance on March 13 is shown in *B*.

of this group had long-standing fibrocavernous tuberculosis throughout the left lung and scattered infiltration in the right upper zone. Extrapleural pneumonolysis for pneumothorax treatment was attempted on the left, but failed because of dense adhesions. The patient has since withstood two stages of a complete thoracoplasty on that side, but we doubt considerably whether it will be possible to arrest the disease.

3. *Some factors complicating pulmonary tuberculosis,* e.g., insufficient cardiovascular reserve, generalized emphysema, asthma, etc., render a

patient unsuitable for thoracoplasty. Only two of our series belong to this group: a patient with bilateral apical cavitation complicated by severe asthma, which she had had since childhood (Fig. 5), and a patient 47 years old who was dyspneic because of long-standing disease with marked emphysema, which had reduced her vital capacity to 900 c.c. The latter patient was temporarily disturbed by the operation, as she suffered from paroxysmal tachycardia for forty-eight hours, but soon recovered, and the sputum is now negative.

If these three "bad risk" groups are considered, it should be obvious that we cannot expect the ultimate results to compare with those of thoracoplasty. The results of thoracoplasty applied to the right cases are so satisfactory that we do not think extrapleural pneumothorax should be used as an alternative measure unless further experience

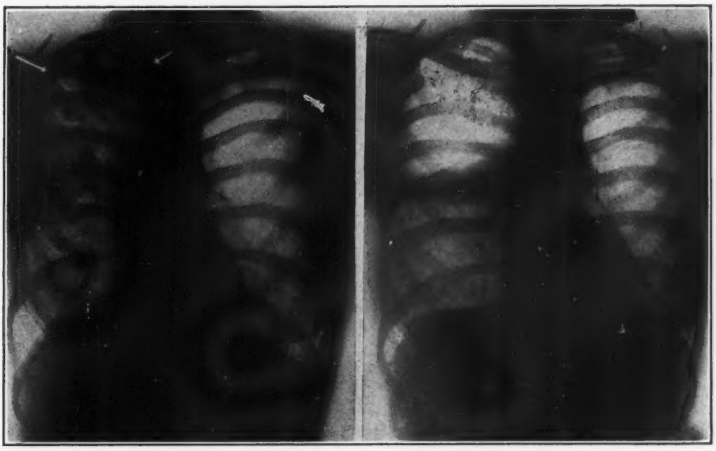

Fig. 4.—H. R., 26-year-old girl, had a left-sided intrapleural pneumothorax and infiltration with some excavation at the right apex (*A*); the latter lesion did not show marked activity. The sputum was positive. A right extrapleural pneumothorax has been performed, resulting in selective collapse of the diseased area (*B*). Patient feels well, has no dyspnea and the sputum is negative.

shows that the same or better results can be obtained at less risk, and, in the light of our present experience, this is not true. We have chosen only those patients who would have previously been rejected as beyond the scope of collapse therapy or, in a few cases, would have been accepted with full knowledge of the great risks being taken.

OPERATIVE TECHNIQUE

The operation has been performed under cyclopropane and oxygen inhalation anesthesia or a combination of local infiltration with paravertebral block of the upper intercostal nerves, using 1 per cent novocain. Both methods have proved satisfactory, but we prefer cyclopropane. The extrapleural separation has not always been entirely painless under regional block, and, when working on the mediastinal side, coughing is frequently caused, which results in excessive movement of the previously

freed part of the lung, thus interrupting the view of the mediastinal pleural reflection. With cyclopropane, owing to the high oxygen concentration combined in its administration, respiratory movements of the lung are minimal, and there is no

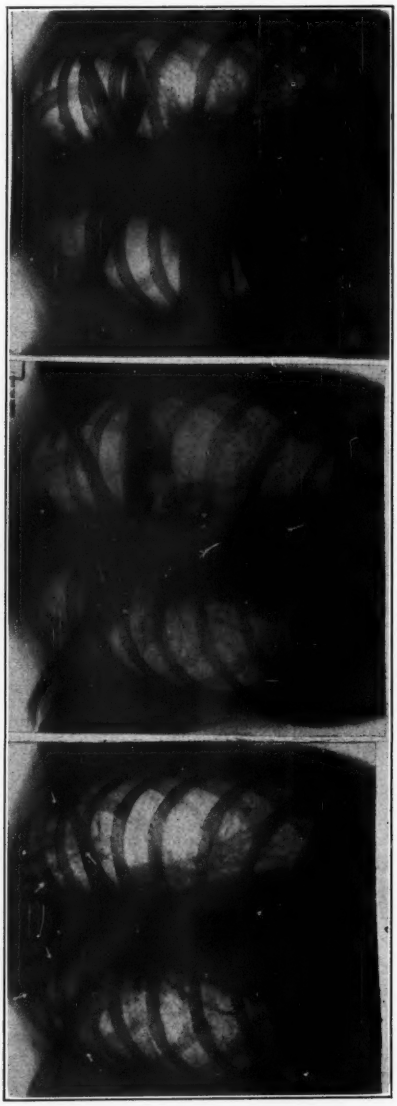

Fig. 5.—A. D., 28-year-old young woman, had had asthma since childhood. She had been in a sanatorium for four and one-half years with a constantly positive sputum. Bilateral selective thoracoplasty had not been undertaken because of the asthma. X-ray film in September, 1937, showed excavation at both apices (*A*). Extrapleural pneumonolysis was performed on the right on Oct. 8 and on the left on Oct. 22, 1937. The sputum remained positive because of a residual cavity on the right side (*B*). On Dec. 20, 1937, the pneumonolysis on the right was increased, exposure being obtained by resection of the fifth rib. Since this, the sputum has been constantly negative, and x-ray film shows no evidence of residual cavitation (*C*).

cough reflex from irritation of the mediastinum if the depth of anesthesia is slightly increased when working in this region.

A curved 8 inch incision with its mid-point over the fourth rib is made parallel to and 1½ inches from the vertebral border of the scapula. It has been found that

less retraction of the scapula is required if the lower end of the incision is curved outward. A smaller incision results in a less adequate exposure of the fourth rib. The muscles are divided in the line of the incision down to serratus posterior superior, which is preserved. This muscle aids in numbering the ribs correctly, as it obtains its lowest attachment to the fifth rib. After the fourth rib is identified, this muscle is separated carefully from its attachment to the fourth and fifth ribs and retracted with the scapula. About 4 inches of the fourth rib are resected subperiosteally extending laterally from the tip of the transverse process. Care is taken not to fragment the periosteum, which is then incised carefully to expose the endothoracic fascia which separates the periosteum from the parietal pleura. We have frequently seen a small quantity of fat lying in the meshes of the endothoracic fascia analogous to the extraperitoneal fat and have found this of help in defining the correct plane for starting the cleavage of the parietal pleura from the endothoracic fascia lining the chest wall. The Germans have aptly described this plane as "subfascial." As soon as it has been defined, fine tissue forceps are applied to the upper margin of the periosteum and adjacent intercostal muscles and are retracted upward and backward by an assistant. A very small sponge held in a

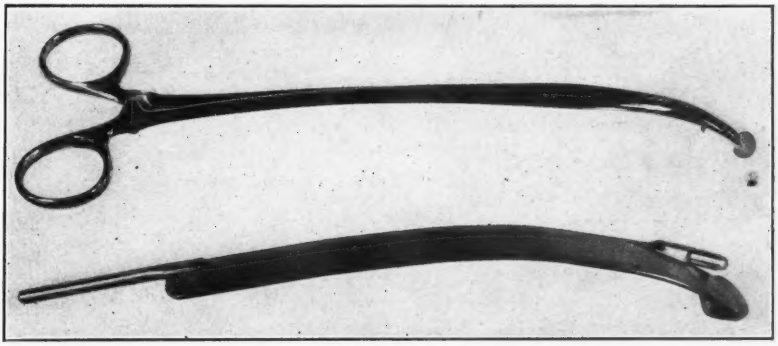

Fig. 6.—At the top is shown the curved artery forceps used for the extrapleural separation. Below is the illuminated retractor used to depress the lung so that the pneumonolysis may be performed under direct vision.

curved artery forceps is gently insinuated into this subfascial plane, thus separating the parietal pleura from the chest wall in the vicinity of the periosteal incision. As soon as a sufficient extrapleural space has been produced to introduce an illuminated retractor (Fig. 6), the usual operating room lights are turned out and the stripping of the pleura continues under intrathoracic illumination and direct vision. A special long-shafted curved forceps (Fig. 6) for holding a small pledget of gauze has been designed, which is useful in carrying out the blunt dissection in the deeper recesses of the space. It has been found that one-half of a bronchoscopic sponge provides about the proper size pledget of gauze. Adhesions have been encountered most frequently in the region of the heads of the ribs and at the apex. As a rule, adhesions of greater density have been found when the disease has been of long duration. Marked thickening of the pleura at the apex, as seen in the roentgenogram, does not necessarily mean that stripping will be difficult. If an attempt to continue the separation in the region of the adhesion is made by increasing the pressure against its attachment to the chest wall, thus avoiding injury to the lung, the intercostal vessels or periosteum of the ribs may be stripped away from the chest wall, and troublesome bleeding may result. It also renders continuation of the pneumonolysis

difficult and dangerous as the separation is no longer subfascial. This complication is obviated if the adhesion is isolated by separating the pleura all around and then cutting the adhesion with scissors; if the divided adhesion bleeds, this can be controlled with a neural clip or ligature. The extrapleural pneumonolysis is continued over the apex and down the mediastinum as far as the hilum. The extent of the stripping anteriorly, laterally, and posteriorly has been varied according to the extent of the disease. In several of our early cases, the separation was insufficient to close all the cavities, and we feel that it is better to err on the side of extending the separation unnecessarily far rather than the reverse. It is easy to allow partial re-expansion of the lung later by decreasing the pneumothorax pressure, whereas increasing the pressures will not always result in the desired increase of the collapse. It is probably wise to extend the separation to a horizontal plane two segments below the radiologic lowest limit of the disease. Complete control of the separation by direct vision is best obtained by working in one place for a short time and packing this region with dry gauze while the operation is continued in another place. On returning to the original site, removal of the gauze usually shows that any

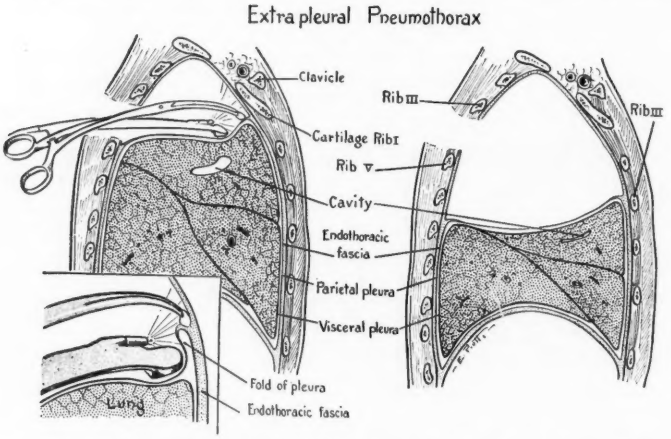

Fig. 7.—Both diagrams represent sagittal sections through the hemithorax. On the left, the illuminated retractor is seen depressing the lung so as to expose the plane of extrapleural separation, which is being continued with a pledget of gauze held in the special artery forceps. The inset shows the small fold of parietal pleura which is produced by retraction of the lung. To avoid opening the pleural cavity, pressure is made with the pledget at the upper limit of this fold, not in the groove at its base. The diagram on the right shows the collapse produced after completion of the pneumonolysis.

oozing has ceased, and the pleural margin, which often forms a fold against the chest wall (see diagram, Fig. 7), can easily be seen. With this technique the pleural cavity has rarely been opened, although, when it has been, no unfavorable complications have resulted.

When the pneumonolysis has been completed to the desired level, the extrapleural space is washed out with warm saline solution and a careful search made for any bleeding points. Absolute hemostasis is very important, as hemorrhage may result in filling of the space with blood clot—a complication which is discussed later. Minute oozing vessels can usually be controlled by pressure with dry gauze; any larger source of hemorrhage has been treated by ligature or neural clip.

The incision in the periosteum is closed with a continuous size 0 plain catgut suture, which is passed through the intercostal muscles on either side and completed

posteriorly by drawing the erector spinae muscles over that end of the incision. This suture line is reinforced by sewing the serratus posterior superior onto its external surface, thus rendering the incision as airtight as possible. After the musculocutaneous incision is closed, manometric pressures of the extrapleural space are measured by introducing a needle through the incision. Air is injected until the pressures fluctuate through a mean of zero.

It is obvious that extreme care should be taken in maintaining absolute asepsis, as infection in the pneumothorax space is likely to prove disastrous. In the four patients (discussed later) in whom this complication arose, the infection was derived from the lung subsequent to operation.

POSTOPERATIVE CARE

On return to the ward, an oxygen tent has rarely been needed even in the very bad-risk patients. Likewise, intravenous infusion has not often been indicated but has been used if the blood pressure has fallen below 100 systolic, so that it may be safe to have the patient sit up soon after operation. The sitting position is considered important in order to prevent a blood clot from adhering to and stretching between the freed apex of the lung and the parietes, as it is feared this clot might later organize and form adhesions transecting the pleural space.

The operation is not associated with much afterpain. Dilaudid (grain $\frac{1}{32}$ to $\frac{1}{48}$) is used on the evening of the operation and repeated during the first forty-eight hours if necessary.

All the patients have developed more or less interstitial emphysema during the first twenty-four hours, but in no case has it caused any distress other than slight tenderness of the affected tissues. The extent has varied from an amount discernible clinically only with difficulty to an area covering the same side of the body above the waist and below the mandible. The extrapleural space, however, soon becomes airtight, and none of our patients have had emphysema persisting more than ten days. Schmidt states that he has never seen any evidence of mediastinal emphysema, and our experience has been similar. Although expectoration of secretions is obviously desirable, an irritative unproductive cough tends to increase the interstitial emphysema and is treated with codeine.

In no case has there been any evidence of retention of sputum for more than thirty-six hours, and sputum charts show clearly that, following pneumonolysis, patients are able to expectorate more efficiently and sooner than after thoracoplasty. In this series there has been no case of atelectasis of the homolateral lower lobe (with one possible exception), and auscultation over this lobe has shown good aeration. Even in a patient with a paralyzed diaphragm on the side of operation and a previous extrapleural pneumonolysis on the other side, breath sounds came through normally at the base, and x-ray films showed no evidence of atelectasis (Fig. 1).

REFILLS

The frequency and amount of air refills to maintain the space so as to give the desired selective collapse have been controlled by frequent radiograms, fluoroscopy, and consideration of the manometric pressures. Our experience has led us to the conclusion that the best program is to obtain a bedside radiogram, with the patient sitting upright on the day following operation. The film should be somewhat overexposed to avoid confusion caused by interstitial emphysema and by increased opacity of the chest wall due to edema. Usually the pneumothorax is seen to contain a variable amount of exudate and the lung to be less collapsed than is ultimately desirable. This being true, a refill is given so that the pressures oscillate through a mean of zero, e.g., +6, –6, or slightly positive if the disease is fibrotic, e.g., +10, –2. The volume required has varied from 100 to 400 c.c. The average patient has required further refills on the second, fourth, sixth, ninth, and twelfth days, the amount necessary to produce a mean of zero very soon decreasing; e.g., 50 to 75 c.c. will often change the pressures from around –4, –12 to +4, –4. Thereafter, refills are usually indicated at a rapidly increasing interval, commonly reaching a stage when only 25 to 50 c.c. are given every two weeks. We agree with Schmidt in opposing the use of high positive pressure in order to force the extent of the collapse, as we feel this may result in the development of a bronchial fistula; also it would be valueless during the early postoperative period, as the air would be forced out into the tissues.

A serohemorrhagic exudate in varying amounts always develops immediately after operation, but this is not considered a complication as it does not interfere with the collapse. It may even be of benefit as it is probable that that part which is not reabsorbed becomes organized and forms a comparatively rigid covering over the collapsed lung. In the patient on whom we had occasion to reoperate, such a tough fibrous covering, 3 to 5 mm. in thickness, was found. If a large exudate has developed, however, we have aspirated and replaced it with air in order to prevent the possibility of the formation of a large coagulum which might result in spreading symphysis between the layers lining the extrapleural space.

COMPLICATIONS

In three cases almost the whole space became filled with blood clots which could not be aspirated through a needle. It has been suggested by several authors[9, 10] that such a clot may liquefy after a few days, thus permitting aspiration, but this did not occur in our three patients. In the first case pneumothorax treatment had to be abandoned, and the patient was left with an extrapleural hemothorax, which may result in sufficient improvement to justify thoracoplasty later. In the second case, a 23-year-old Portuguese girl with extensive bilateral disease and

a right-sided intrapleural pneumothorax, was treated with extrapleural pneumothorax for a rapidly progressing lesion on the left. Two weeks later the patient was transferred back to the sanatorium unimproved and died two months after operation, the only death in the series. In the third case which occurred after these two failures, we followed the suggestion of Roberts[11] and inserted a trocar and cannula and aspirated the blood clot by means of suction applied to a rubber catheter. After the extrapleural space was washed out with saline solution, examination with a thoracoscope showed that all the blood clot had been removed, leaving behind some irregular strands of fibrin. There has been no recurrence of the hemorrhage, and x-ray film shows a good pneumothorax. We propose to adopt this method of treatment in any future case.

Four patients have developed infection in the extrapleural space. Three of these have definite evidence of a bronchial fistula, and we think it is probable that the fourth patient also developed a communication between the lung and the extrapleural space. In one patient the extrapleural pneumothorax was combined with a homolateral intrapleural pneumothorax which had originated spontaneously and been maintained artificially. The operation was performed to overcome complete adherence of the lung at the apex, and separation was successfully accomplished, but, in doing so, the pleura was opened so that the extrapleural and intrapleural spaces communicated freely. The patient did well for two months and then suddenly developed a superimposed spontaneous pneumothorax with subsequent infection. In view of the spontaneous origin of the intrapleural pneumothorax, it would seem reasonable to suppose that the fistula is a complication of this rather than of the extrapleural pneumothorax. Two patients developed fistulas the third week after operation. One is being treated with aspiration and irrigation, which has resulted in steady improvement, and the other has been treated with drainage through an intercostal catheter, which has reduced the fever. The fourth developed an extrapleural empyema and died two months after operation, the patient referred to above.

The development of a bronchoextrapleural fistula in some instances is very likely due to necrosis of a portion of the lateral wall of the cavity as a consequence of the loss of its blood supply from vascularized chest wall adhesions. Monod[12] maintains that this complication will inevitably result if the procedure is used when a large peripherally located cavity exists. He emphasizes the importance of definitely determining the location of the cavity before carrying out extrapleural pneumothorax.

When describing the operation, we suggested that the pleural separation should be carried to a horizontal level two segments below the radiologic lowest limit of the diseased area. This standard has been taken after due consideration of those cases in which inadequate sep-

aration has resulted in incomplete collapse of the diseased portion of lung or seemed to make maintenance of the extrapleural pneumothorax less certain. In one such case we reoperated and extended the separation down farther with a satisfactory result (Fig. 5). In another, the air has been replaced by paraffin oil, as the small space would have soon been obliterated by re-expansion of the lung. This replacement has worked well, as the patient remains in excellent condition with a negative sputum. In another, the space was lost after the patient's return to the sanatorium. The postoperative record of these two patients would apparently favor the opinion held by many lacking in experience with the procedure that satisfactory collapse cannot be maintained by air refills. We have found that the lung always re-expands a small amount during the six weeks immediately following the first two postoperative weeks but that the collapse then becomes stabilized, probably because of the formation of an inelastic fibrous covering over the lung.

One further postoperative complication remains to be described. This occurred in a 46-year-old patient with a giant spherical cavity occupying the upper third of the right hemithorax—the type of lesion that has been described as a consequence of a ball-valve bronchial communication which allows air to enter but not leave the cavity. Since operation, the patient has been bronchoscoped, and the upper lobe bronchial orifice seen to be grossly stenosed. As the patient was febrile, dyspneic, and had intestinal tuberculosis, and in view of the notorious difficulty with which such cavities are closed by thoracoplasty, it was decided to attempt closure by an extrapleural pneumothorax. Adequate pneumonolysis was obtained at the operation. During the first twelve hours the patient coughed frequently, resulting in extensive interstitial emphysema. Refills of air were given in the morning and evening of the day after operation, and it was observed that large amounts of air were injected without alteration of the manometric pressures. This led to the suspicion that the pulmonary cavity was being insufflated, and 1 cm. of methylene blue was therefore injected and was subsequently expectorated. X-ray films taken after this showed ballooning of the cavity, with a small pocket of air in the extrapleural space at the extreme apex. We have since been able to find this pocket with a needle, and air refills have resulted in re-establishing the extrapleural pneumothorax. Evidences of a bronchoextrapleural fistula appeared the fourth postoperative week. The unintentional perforation of the cavity wall with the pneumothorax needle could account for the formation of the fistula in this case. A lateral roentgenogram shows that the extrapleural space occupies the upper half of the hemithorax, and the cavity, which is not over 1.5 cm. in diameter, lies below in the vertebral gutter. Evidence is lacking in this case, therefore, that the lateral

wall of the cavity became necrotic because of its separation from the chest wall. Regardless of this complication, the patient has improved sufficiently to consider thoracoplasty.

More complications were encountered among the first patients of the series, indicating that experience with the operation will enable us to prevent or treat many of them more effectively in the future. Emphasis has been laid on the complications, as we feel that control of the postoperative course is far more intricate than the actual operation, and it is hoped that some of our unfortunate experiences may prevent others having similar trouble. In view of the experience necessary for proper stabilization of the extrapleural pneumothorax, we are of the opinion that the operation should not be performed unless competent care is obtainable afterward.

This is a preliminary report including cases operated on during the last month, and it is, therefore, impossible to tabulate the results or to forecast accurately the best method for dealing with the extrapleural space when the patient's pulmonary disease has remained arrested for a sufficient period. There appear to be four possibilities to the latter problem: (1) maintain the extrapleural pneumothorax permanently; (2) replace the air by sterile oil; (3) obliterate the space by allowing re-expansion of the lung; (4) obliterate the space by removing the ribs over it and render the pneumothorax collapse permanent by thoracoplasty. It is probable that re-expansion of the lung, even if desirable, would not occur in many of the cases because of the inelastic fibrous tissue covering.

We believe that most of the patients of our present series will eventually require conversion of the extrapleural pneumothorax to the permanent collapse of thoracoplasty. This prediction is made because of the extensive disease present in those selected for this form of treatment. Should the operation eventually be applied more widely to include young patients with less extensive disease, the ultimate fate of the space would be subject to the same rules that apply to an intrapleural pneumothorax.

Our experience to date has led us to feel that extrapleural pneumothorax will become a well-established form of collapse therapy and a valuable addition to the surgical armamentarium in the treatment of pulmonary tuberculosis. The operation will not supplant upper selective thoracoplasty. Extrapleural pneumothorax will probably find its greatest usefulness in: (1) extensive bilateral disease when selective collapse by intrapleural pneumothorax is impossible; and (2) less extensive but active disease, when collapse therapy is urgently needed but pneumothorax is impossible or unsatisfactory, diaphragmatic paralysis is considered inadequate, and yet thoracoplasty carries too great a risk or is definitely contraindicated.

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RESECTION OF THE THORACIC ESOPHAGUS

A Clinical and Experimental Study*

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CARCINOMA of the thoracic esophagus and the cardiac end of the stomach has a high mortality, regardless of the type of treatment instituted. This can be attributed both to a delayed correct diagnosis and to the dangers associated with its surgical treatment. Carcinoma of the esophagus is very insidious in its onset, and when the first symptoms are noted, such as difficulty in swallowing, the condition is already far advanced.

Much attention was given the surgical treatment of this condition as early as twenty-five years ago. Experimental work was carried out, and surgical resection of the tumor was attempted in a number of patients. The results were unsatisfactory, however, and treatment was relinquished to the radiologist. Palliative measures including gastrostomy, radium, and deep x-ray therapy have maintained patients in comparatively good health for as long as a few months to two years. The lack of complete cures, however, has again stimulated activity in the operative treatment of this condition. A ray of hope lies in the fact that successful surgical removal of carcinoma of the esophagus is not impossible. Most of the patients in which this was accomplished have died subsequently of metastases. The only recorded patient to survive five years or longer was one who had a successful resection by Torek[1] in 1913. This patient was a woman 67 years of age who died of pneumonia thirteen years following the successful removal of a carcinoma of the midthoracic esophagus. This successful case naturally stimulated many attempts at the surgical alleviation of this condition, and many types of operations were attempted. A review of the literature reveals thirty-four successful resections of the esophagus for carcinoma reported by eighteen authors since Torek's case in 1913. Seventeen of these resections have been performed within the last three years, the majority by an operation similar to that described by Torek. The largest series of cases was reported by Ohsawa in 1934.[2] The length of the survival period following operation was not given. He reported four successful resections in twelve cases of carcinoma of the thoracic esophagus and eight successful resections out of fourteen cases of carcinoma involving

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the cardia and esophagus, in which 2 to 5 cm. of the esophagus were resected. He also reported one successful resection out of five cases of carcinoma of the esophagus in which 6 to 8 cm. of that organ were removed, and two successful cases in which an esophagojejunostomy was performed.

Carcinoma of the esophagus, like carcinoma of the lung, is difficult to diagnose in its early stages. For this reason it is important that members of the profession as well as the laity become conscious of its frequent occurrence. Since interest in carcinoma of the lung was stimulated by the first successful complete pneumonectomy by Graham,[3] five years ago, the number of patients remaining symptom-free for one year or more following resection has gradually increased. Undoubtedly early diagnosis has played a considerable role in making possible this advance in the treatment of carcinoma of the lung. Although only limited success has attended the surgical treatment of carcinoma of the esophagus up to the present time, with the diagnosis of early lesions it should be possible to improve this considerably.

Failure of operative procedures has been chiefly due to mediastinitis and infection of the pleural cavity as the result of soiling during the resection of the tumor. Necrosis of the cut end of the esophagus, due to poor circulation, has undoubtedly played a role in the cases where an anastomosis was performed.

Inasmuch as the general condition of these patients is usually below normal, pneumonia following operation has not infrequently been the cause of death. Postoperative hemorrhage and pneumothorax have been responsible for unsuccessful results in some cases, although at the present time these factors are much more controllable than formerly. In the operative procedure where the entire esophagus is freed from the surrounding parts and resected through an abdominal and cervical incision, mediastinal infection and postoperative hemorrhage would seem much more likely to occur, since the esophagus is likely to be torn during the procedure, and the tear is most likely to occur at the site of the carcinoma. Postoperative diaphragmatic hernia, cardiorespiratory failure resulting from injury to the vagus, and inanition have also been reported to have been causes of failure.

The majority of the successful cases reported by American and European authors involved removal of the thoracic esophagus by bringing the upper end out through a cervical incision. The continuity of the alimentary canal was restored by the use of a rubber tube connecting the upper esophagus with a gastrostomy opening. An exception to this was the case reported by Lilienthal,[4] in which the resection was performed extrapleurally. A pedicle skin flap was used to unite the two ends after the resection, the operation being done in two stages without employing gastrostomy. The patient lived sixteen months. Conversely, most of the cases reported by the Japanese have been performed either through

the abdomen and diaphragm or through an incision opening both the peritoneal and pleural cavities, the esophagus being united with the stomach or jejunum by suture, following the resection of the tumor. They believe that their success has been due mainly to the use of free thoracotomy without positive pressure anesthesia. Stress is also laid on the necessity of the anastomosis being performed without tension on the suture line.

A vast amount of experimental investigation of this problem, employing many ingenious operative procedures, has been reported. References to the greater part of this work prior to 1921 are included in Lilienthal's report[4] of a successful extrapleural resection in the same year. In 1923, Miller and Andrus[5] resected a portion of the lower thoracic esophagus in eighteen dogs and reunited the esophagus and stomach by suture. Four dogs died of hemorrhage and shock, and three died of a leak of the anastomosis. Of the remaining eleven in which the suture line was intact, three died of infection and four died of distemper 3, 7, 17, and 20 days after operation, respectively. Saint and Mann[6] reported in 1929 a series of five thoracic-esophageal resections in dogs with reanastomosis by suture. One died of a leak of the anastomosis and one of hemorrhage. Three functioned well, one living 301 days. Experimental work by Ohsawa[2] in 1934 employed fifty-four dogs. A number of approaches were described, but the technique of resection was similar in all cases. A two- or three-layer interrupted silk suture technique was used. Forty animals died of shock, empyema, or leakage of the anastomosis from one to seven days following operation. Four lived for 35, 50, 63, and 78 days, and ten more lived for about three weeks. These last two groups died of inanition at the end of those periods.

A clinical case of carcinoma of the cardiac end of the stomach, involving the lower end of the esophagus, was seen in March, 1937. This was the stimulus for the experimental work being reported at this time. A brief résumé of this case follows:

An 18-year-old male was admitted to the hospital on March 23, complaining of having vomited blood, perhaps two or three cupfuls in amount, three times in the preceding two hours. There was no history of previous disturbances of any kind. It was assumed that the difficulty was due to a bleeding ulcer, and he was put on bed rest. Physical examination was essentially normal. The stools were found to contain blood. On April 1, an x-ray study revealed a filling defect by a mass in the lower part of the esophagus immediately above the cardiac orifice, partially obstructing the flow of barium. On April 5, an esophagoscopy was performed, and a soft, friable, nodular tumor was found at the lower end of the esophagus. It bled easily when two biopsies were taken. Microscopic sections revealed an adenocarcinoma. On April 14, an incision was made through the upper left abdomen in the direction of the seventh left intercostal space and carried up through this interspace to the axillary line. Both the upper abdomen and chest were opened, and the diaphragm was split from its periphery to the esophageal hiatus. This afforded very good exposure, and mobilization of the lower esophagus and stomach was easily achieved. The tumor was found to involve a considerable portion of the lesser curvature of the stomach,

necessitating the ligation of the blood supply in that region. It was therefore thought advisable to do a complete gastrectomy along with resection of the lower two inches of the esophagus. A loop of jejunum was then brought up with some difficulty, and an end-to-side anastomosis between the esophagus and jejunum was carried out. An anastomosis was also made between the two limbs of the jejunum, and a Witzel jejunostomy was made in the proximal limb of the loop of the jejunum. There was considerable tension on the suture line between the esophagus and jejunum. The diaphragm was then closed about the jejunum, and the suture was carried out to the periphery. Next, the chest and abdominal wounds were closed without drainage. The patient stood the operation without any evidence of shock, the blood pressure remaining above, or around, 100 systolic throughout. Following the operation there was a marked febrile reaction. The left pleural cavity remained obliterated, and the chest, abdominal, and diaphragmatic wounds were healing well on the sixth post-operative day when the patient expired. A fair amount of exudate was found in the

Fig. 1.—Photograph of specimen removed from patient at operation showing involvement of the lower esophagus and the lesser curvature of the stomach by malignant tumor.

right pleural cavity, which was in contact with a leak of the posteromedial portion of the anastomosis between the jejunum and esophagus. There was also marked kinking at the duodenojejunal junction, with extreme dilatation of the entire duodenum. Along with the infection of the right pleural cavity, there was definite evidence of mediastinitis.

REPORT OF EXPERIMENTS

Dogs were used exclusively and were divided into two groups. In the first group of thirty-one dogs, 2.5 to 10.0 cm. of the lower esophagus, with or without some of the cardia, were resected, and the esophagus re-united with the stomach by suture (Table I). In the second group of twenty-nine dogs a part or all of the thoracic esophagus was resected, and a fistula was produced in the cervical esophagus (Table II). These

TABLE I

GROUP I. RESECTION OF LOWER THORACIC ESOPHAGUS WITH REUNION OF THE STOMACH AND ESOPHAGUS BY SUTURE

OPERATION*	EXPERIMENTS	D—DIED K—KILLED	LEAK	PNEUMONIA	REMARKS	SUCCESS
a.	6	D—4 (3-5 dy.) K—2 (3 wk.) (11 wk.)	3	0	1—died, 15 wk. Cause unknown 2—marked stenosis where continuous suture was employed	3
b.	5	D—5 (2-5 dy.)	2	1	1—open pneumothorax 1—shock 1—leak from tension on suture line 1—bilateral pneumonia 1—leak of anastomoses	0
c.	13	D—6	4 (cutting needle used)	2	1—intussusception 3—diaphragmatic hernia 2—living 194 and 220 days after operation	7
d.	7	D—5 1 living, 1 mo. 1 living, 2 wk.	3	0	Only small resections possible without tension and resultant leak 1—died of asphyxia few hours postoperative 1—died of asphyxia during operation	2

*a. Resection of esophagus and cardia with end-to-end anastomosis.
b. Resection of esophagus and cardia with end-to-side anastomosis.
c. Resection of esophagus with end-to-side anastomosis (one stage).
d. Resection of esophagus with end-to-side anastomosis (two stage).

TABLE II

GROUP II. A PART OR ALL OF THE THORACIC ESOPHAGUS RESECTED WITHOUT RE-ESTABLISHMENT OF CONTINUITY OF THE ALIMENTARY CANAL

OPERATION*	EXPERIMENTS	D—DIED K—KILLED	LEAK	PNEUMONIA	NECK WOUND INFECTION AND MEDIASTINITIS	REMARKS	SUCCESS
a. 1.	12	D (2-8 dy.)	0	7	6	1—pneumothorax	0
2.	3	D (2-5 dy.)	0	1	1	1—cause unknown (4 dy. postoperative)	0
b.	7	D (1-7 dy.) 1 (17 dy.)	5	1	0	1—lived 17 days	0
c.	7	D—5 (2-4 dy.) K—2 (16 dy.)	2	1	2	2—empyema 1—dilatation of stomach	2

*a. Total removal of the thoracic esophagus.
1. Thoracocervical operation.
2. Abdominocervical operation.
b. Low thoracic esophageal resection.
c. High thoracic esophageal resection.

dogs were fed through a gastrostomy tube, whereas those in the first group took food by mouth after the first three or four days following operation.

In the first group of animals four types of operative approach were used: (1) through the chest and dome of the diaphragm, (2) through the chest and esophageal hiatus, (3) through the abdominal and thoracic wall, splitting the diaphragm, (4) through the abdomen and esophageal hiatus.

The type of approach was partly determined by the level of the esophagus to be resected. When a part of the cardia was to be resected, the diaphragm was opened at the esophageal hiatus, and the cardia was mobilized. If only the thoracic esophagus was resected, the dome of the diaphragm was opened transpleurally and a portion of the stomach lifted through for anastomosis with the esophagus. This proved to be quite simple and was the operation more frequently employed.

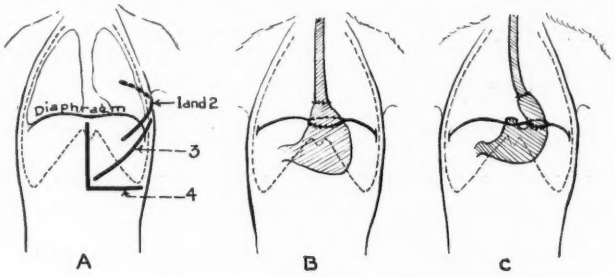


Fig. 2.—Diagrammatic illustrations of incisions used and two types of operations performed. *A*, incisions; *B*, through esophageal hiatus; *C*, through dome of diaphragm.

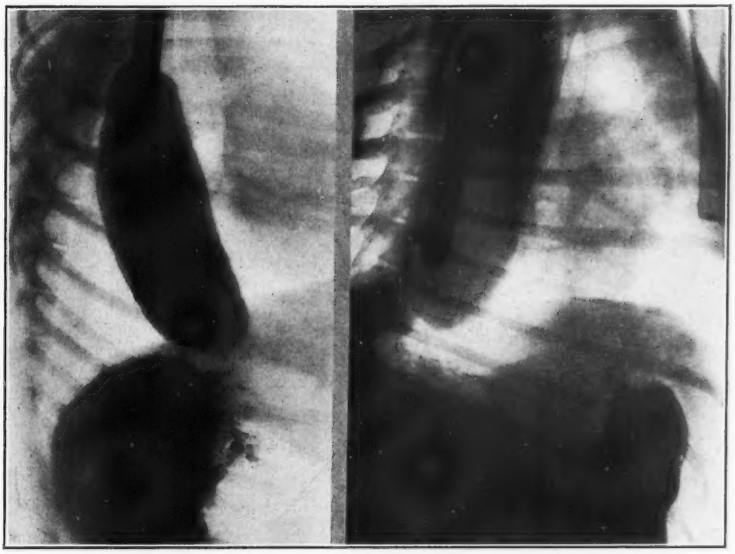
In the first group, four types of resection operations were performed (see Table I):

a. Resection of esophagus and cardia with end-to-end anastomosis.
b. Resection of esophagus and cardia with end-to-side anastomosis.
c. Resection of esophagus with end-to-side anastomosis (1 stage).
d. Resection of esophagus with end-to-side anastomosis (2 stage).

EXPERIMENTAL METHODS

Intratracheal positive pressure ether anesthesia preceded by 0.015 morphine sulfate hypodermically, was routinely employed. The thoracic approach was usually made through the eighth or ninth intercostal space. The abdominal approach was through a right-angle incision; the vertical arm was in the midline, and the horizontal extended from its inferior end, laterally beneath the subcostal margin. The incision opening both peritoneal and pleural cavities extended downward and forward through the ninth left intercostal

space, across the costal arch, and through the left upper abdominal wall for 2 or 3 inches. The diaphragm was then split from its



A. *B.*

Fig. 3.—Dog No. 260. *A*, X-ray picture following barium meal, showing marked stenosis at point of anastomosis. *B*, X-ray of same dog, showing lateral anastomosis around the point of obstruction.

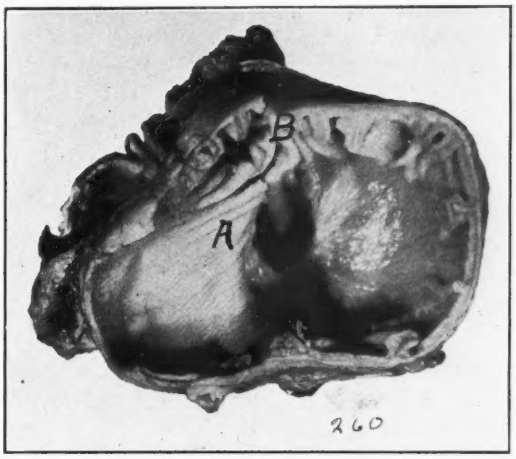


Fig. 4.—Photograph of specimen of dog No. 260, sacrificed eleven weeks following first operation. Note large communication between esophagus and stomach at (A) and almost completely occluded communication at (B).

periphery to the esophageal hiatus. Great care was exercised to avoid contamination, especially during the resection and anastomosis.

Clean instruments and drapes were used for closure of wounds after complete obliteration of the surgical pneumothorax and thorough washing of the hands in alcohol. The diaphragm was routinely paralyzed by crushing the phrenic nerve. Mobilization of the esophagus included only that portion to be resected, care being exercised to spare the blood supply for the portion remaining for anastomosis. Soiling from the upper end was at times prevented by inserting a small sponge into its lumen. There was less obscuring of the field of operation by bleeding

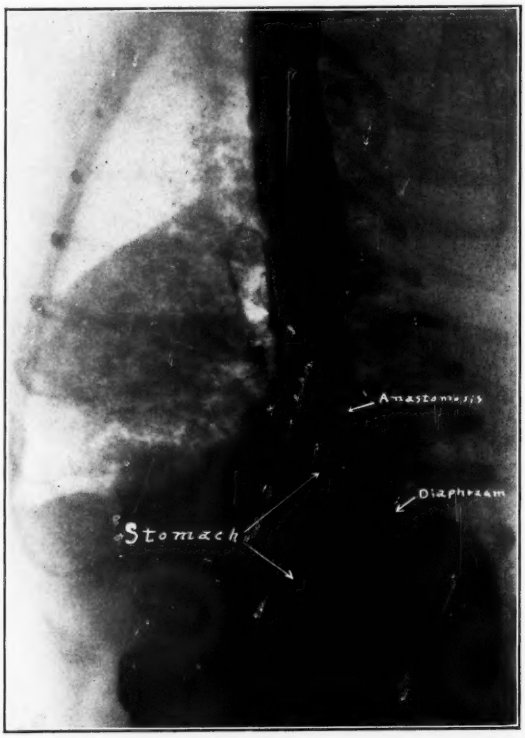


Fig. 5.—Dog No. 749. X-ray, following barium meal, revealing no evidence of obstruction. The site of anastomosis and level of the diaphragm are readily seen (See Table III).

from this end when a soft clamp, no stronger than pressure between two fingers, was used during the application of the first row of interrupted sutures. The entire field was walled off by warm, moist gauze packs before the esophagus or stomach was divided.

With the exception of the first two animals, a two-layer interrupted linen suture technique was used almost routinely throughout. A two-layer continuous suture was used in the first two dogs, and marked stenosis of the anastomosis developed in both animals.

At times, some tension on the suture line was noticed when the anastomosis was complete. These cases almost routinely resulted in death from a leak of the anastomosis. When tension was avoided, a leak seldom occurred.

RESULTS

Group I a.—Three of the six dogs in this series died of a leak of the anastomosis (394, 920, and 816). Although the other three lived for some time, they vomited considerably. In two dogs (260 and 263) this was thought to be due to stenosis of the anastomosis, resulting from the use of a continuous suture; however, vomiting continued after reoperation and a lateral side-to-side anastomosis around the ob-

Fig. 6.—Photograph of chest of dog No. 749 sacrificed 3 weeks following operation. No fluid in the pleural cavity. Note portion of stomach in thorax and site of anastomosis beneath the arch of the aorta.

struction. In these dogs the vagi were damaged considerably, a factor which may have been responsible for the vomiting. Two of the three presented no obstruction when sacrificed at three weeks (805) and eleven weeks (260) following operation. The third dog (263) died for no obvious reason at the end of fifteen weeks.

Group I b.—In three of the five dogs of this series the abdominothoracic approach was used and probably contributed much to the unsuccessful results. One of these died of shock in twenty-four hours (335), one of bilateral pneumonia in two days (911), and one from leak of the anastomosis on the third day. Of the two remaining, one died of leak from tension on the suture line, produced by attempting to suture the diaphragm above the anastomosis. The other died of an open pneumothorax from infection of the chest wall.

TABLE III

DETAILED STUDY OF EXPERIMENTS IN GROUP I

DOG (NO.)	GROUP	CM. LENGTH RESECTED	APPROACH	DIED OR SACRIFICED—TIME	LEAK OF ANASTOMOSIS	RESULTS	SUCCESS
260	1—a	E* 3.75 S† 2.5	4	S—11 weeks	0	Reanastomosis about stenosis but vomiting still occurred	Yes
263	1—a	E 5.0 S 2.5	4	D—15 weeks	0	Unexplained death	Yes
394	1—a	E 2.5 S 5.0	2	D— 3 days	Yes	Infection from leak. Cutting needle	—
920	1—a	E 5.0	2	D— 5 days	Yes	Infection from leak	—
805	1—a	E 7.5	2	S— 3 weeks	0	Considerable vomiting	Yes
816	1—a	E 5.0	2	D— 4 days	Yes	Infection from leak	—
335	1—b	E 2.5 S 2.5	3	D—24 hours	0	Shock	—
345	1—b	E 6.75 S 2.5	2	D— 2 days	Yes	Infection. Much tension on anastomosis	
266	1—b	E 5.0 S 3.75	2	D— 5 days	0	Open pneumothorax from infected chest wall	—
911	1—b	E 5.0	3	D— 2 days	0	Bilateral pneumonia	—
817	1—b	E 4.0	3	D— 3 days	Yes	Infection from leak	—
245	1—c	E 7.5	1	S—12 weeks	0	Diaphragmatic hernia	Yes
246	1—c	E 5.0	1	S—11 days	0	Intussusception	Yes
706	1—c	E 7.5	1	Living 7.3 months	0	Hernia repaired	Yes
692	1—c	E 8.5	1	D— 4 days	Yes	Cutting needle	—
747	1—c	E 7.5	1	D— 4 days	Yes	Cutting needle—tension	—
761	1—c	E 8.5	1	D— 2 days	Yes	Cutting needle—tension	—
752	1—c	E 10.0	1	D— 4 days	Yes	Cutting needle—tension	—
749	1—c	E 4.0	1	S— 3 weeks	0	No hernia or vomiting	Yes
788	1—c	E 7.5	1	Living 6.5 months	0	Some vomiting. No obstruction	Yes
691	1—c	E 7.5	1	S—5⅛ weeks	0	Suppurative arthritis	Yes
953	1—c	E 6.5	1	D— 5 days	0	Pneumonia	—
972	1—c	E 6.0	1	D— 2 days	0	Pneumonia	—
878	1—c	E 6.0	1	Living 126 days	0	Hernia repaired	Yes
195	1—d		1	D— 4 days	Yes	Tension on suture line	—
212	1—d	4 to 6 cm.	1	Living 1 month +	Yes	No vomiting	Yes
215	1—d	resected in most	1	D on table	0	Aspiration asphyxia	—
112	1—d	of	1	D—5 days	Yes	Mediastinitis and pleuritis	—
259	1—d	this group	1	D—few hours	—	Much pleural exudate following first stage	—
260	1—d		1	Living 2 weeks	—	Appears well	Yes
261	1—d		1	D—5 days	Yes	Empyema	—

*E=esophagus. †S=stomach.

Group I c.—Leak of the anastomosis occurred in only four of the thirteen dogs in this series, and a cutting needle was used for applying the suture in each case. When a round needle was employed, no leak resulted. Of these nine, two died of pneumonia on the second (972) and fifth (953) day following operation. Four of the remaining seven animals were sacrificed 11 days (246), 21 days (749), 38 days (691), and 84 days (245) following operation. One (878) died 126 days after operation of severe mange and inanition. The other two are living 194 days (788) and 220 days (706) after operation. Three developed postoperative diaphragmatic hernia (245, 706, and 878). Two of these were repaired with relief of symptoms (vomiting and loss of weight).

Group I d.—In this series of seven dogs, the operation employed in Group I c was divided into two stages. The first stage entailed mobilization of the esophagus and stomach at the hiatus, and the suturing of the fundus of the stomach above the diaphragm. At the second stage, seven to fourteen days later, resection of 4 to 6 cm. of esophagus with gastroesophagostomy was performed. At the second stage variable amounts of fibrinous or fibrous adhesions were present, and the stomach was covered with granulation tissue. For this reason the tissues were not pliable, and

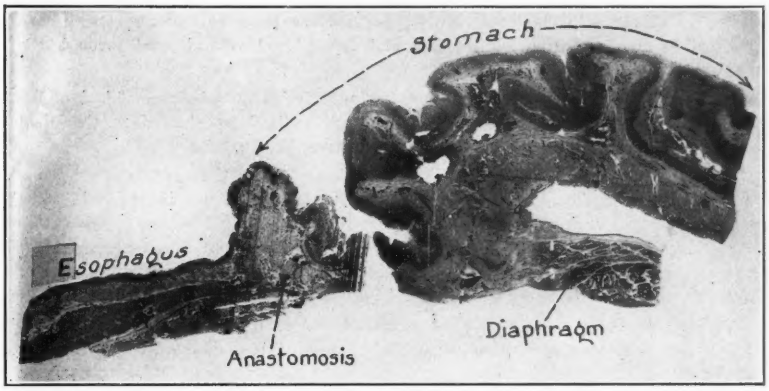


Fig. 7.—Microscopic section (two) taken longitudinally through the site of anastomosis and attachment of stomach to diaphragm. Complete regeneration of the esophageal and gastric mucosa is shown at the site of anastomosis. There is solid union also seen in the attachment of stomach to the diaphragm.

only short segments could be resected without putting the suture line of the anastomosis under tension. Thus three of the seven died on the fourth, fifth, and fifth days, respectively, due to leak of the anastomosis. One died due to aspiration of stomach contents during the second stage operation. One died of asphyxia due to massive pleural exudate following the first stage. Two were living and functioning well, two weeks, and one month, following the second stage operation (Table III).

The second group of 29 dogs was subdivided into three parts according to the amount and level of resection (see Table II).

a. Total removal of the thoracic esophagus
   1. Thoracocervical operation
   2. Abdominocervical operation
b. Low thoracic esophageal resection
c. High thoracic esophageal resection

In the first series of fifteen dogs the entire thoracic esophagus was mobilized, either through an incision in the lower left chest wall, twelve, or in the upper ab-

domen, three. Where the transthoracic approach was used, the lower esophagus was divided between ligatures, the lower end being inverted with a purse-string suture. When the abdominal approach was used, mobilization of the esophagus and stomach at the hiatus was accomplished, and the "tunneling operation" described by Fischer was performed. In either case, the esophagus was brought out through a cervical incision, care being exercised that no obstruction to the esophagus remained. A mushroom catheter gastrostomy completed the operation. Postoperative care included intravenous Ringer's solution and liquid food administered through the gastrostomy tube. Although much attention was given to aseptic technique, feeding, etc., no animal survived the procedure longer than eight days. A rubber dam was placed over the end to be resected, with the hope of eliminating the factor of infection, but the end results were the same. Eight dogs died of pneumonia between two and eight days after operation. Seven died of cellulitis of the cervical wound and mediastinitis.

In the second series (b) of seven dogs a resection of 5 to 7 cm. of the lower thoracic esophagus was performed transpleurally. The ends were closed by ligature or suture and inverted by one or two purse-string sutures. A mushroom gastrostomy completed the operation. A fistula of the cervical esophagus performed according to the technique of Dragstedt[7] always preceded the resection. Postoperative care included intravenous Ringer's solution and liquid food administered through the gastrostomy tube.

Six of the seven animals died in from one to seven days, five because of leak of the upper blind esophagus, and one of pneumonia. One lived seventeen days, then died of pneumonia and opening of the upper esophageal stump, with empyema.

In the third series (c) of seven dogs, resection of 2.5 to 4 cm. of upper thoracic esophagus was performed similar to the procedure carried out in series b. The upper esophageal stump was closed by suture in six, and ligation in one, this stump being inverted by a purse-string suture. A cervical esophageal fistula preceding the resection, a gastrostomy at the time of resection, and the postoperative care were the same as in the preceding group (b).

Two of the seven were well when sacrificed sixteen days after operation. Both closed esophageal stumps were solidly healed. One died in one day of acute dilatation of the stomach; one died of empyema on the second day; one died of pneumonia on the third day, and two died of mediastinitis and empyema, due to reopening of both stumps in one dog and the upper stump in one dog, four days following operation.

DISCUSSION

A study of the blood supply of the esophagus is pertinent to the operative treatment of lesions of that organ. Ohsawa demonstrated by injection with a solution of bichloride of mercury into the aorta of fresh cadavers and animals that "the segments receiving a poor blood supply were the cervical and lower thoracic." The latter is still further enhanced by the mobilization of the stomach and lower esophagus from the diaphragm. The anastomosis should therefore be more likely to hold when performed several inches above the stomach, as was the case in Group I c. Mobilization should only include that portion of the esophagus for resection and anastomosis.

Ohsawa emphasizes the great danger of necrosis of the fundus following ligation of the coronary sinistra artery at the lesser curvature. Kirchner and others, however, have concluded from experiments that

this complication does not often occur. It was never observed in our series of animals. This is an important factor, for in carcinoma involving much of the cardia this artery must be sacrificed. In a successful resection of 3 inches of the lower thoracic esophagus and 1 inch of the stomach in a patient with carcinoma in that region (reported in a following communication) it was necessary to sacrifice this artery. Not-

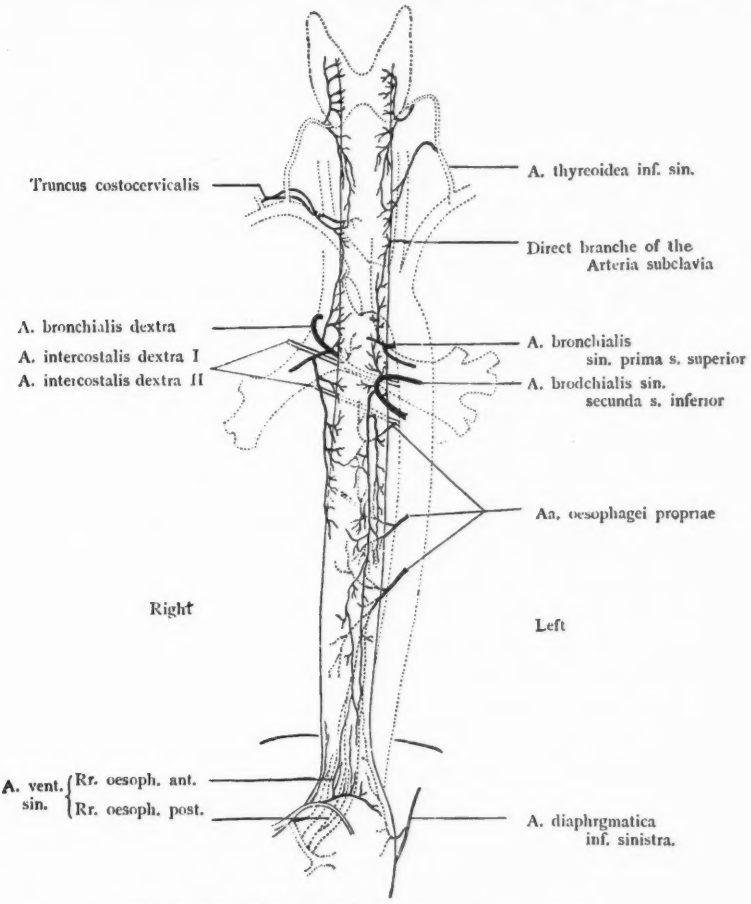


Fig. 8.—Circulation of the esophagus (after Ohsawa).

withstanding this, the opening made in the fundus of the stomach, for anastomosis with the esophagus by suture, bled freely, and following the operation the convalescence was uneventful, the anastomosis functioning well.

Since infection is one of the major hazards of this operation, every precaution was taken not only to prevent contamination of the pleural

cavity and mediastinum, but of the chest wall as well. Complete walling-off with warm moist sponge pads prevented gross contamination during resection and resuture. Spilling of contents of the upper esophageal segment during resuture was prevented by a small sponge inserted into its lumen, or by the application of a soft clamp. The latter was more satisfactory since it prevented constant oozing and obscuring of the field. Soiling was definitely less where an end-to-side anastomosis was made between the esophagus and fundus of the stomach, the cardiac end being closed by a two-layer continuous suture. This procedure proved to be the more desirable also from the technical standpoint. Our technique was similar to that of Miller and Andrus[6] in this respect, whereas most other authors have employed the end-to-end type of anastomosis.

Postoperative vomiting was a prominent feature in some animals, especially when the vagi were severely traumatized or severed during the mobilization of esophagus and cardia. It was either absent or very mild when these nerves were spared.

One of the major factors to determine the success or failure of the operation was tension on the suture line of the anastomosis. This was purposely applied in some animals and routinely resulted in leak of the anastomosis.

Stenosis of the anastomosis was noted in only two dogs, in both of which a continuous suture was employed. In a few dogs a two-layer continuous suture was employed but was interrupted at four points. None of these developed symptoms of obstruction.

Diaphragmatic hernia developed in three of the ten dogs surviving resection and resuture. Continued vomiting and loss of weight was an early manifestation of this complication. Because of the lack of a cardiac sphincter, vomiting was probably more pronounced than would have been the case with a normal stomach. Repair of the defect relieved the symptoms in two of these animals.

The results of the second group of experiments reveal almost uniformly fatal termination. This contrasted very strikingly to the mortality of Group I. The reason for this was not always clear. Since Dragstedt[7] has demonstrated the frequency of pneumonia in dogs having esophageal obstruction, every precaution was taken to insure against obstruction in these cases. In spite of this, eight of fifteen dogs in Group IIa died of pneumonia. Shock did not appear to be a factor, since blood pressure tracings made during one of these operations remained fairly constant. Mediastinitis extending from a cellulitis of the neck wound proved fatal in the remainder of this group.

Fluoroscopy, following a barium meal in two dogs of the first group who had developed stenosis of the anastomosis, suggested strongly the cause of failure of the low resection operation. Marked esophageal peristalsis attempting to overcome the obstruction was observed in both dogs. That the upper stump always reopened and the lower remained

closed lent considerable support to the hypophysis that the peristaltic action was responsible for its reopening. When the resection was high in the thorax, this factor was almost completely eliminated and was reflected in the partial success of the resections made at this level.

SUMMARY

Resection of as much as 4 inches of the thoracic esophagus with gastroesophagostomy was successfully performed in dogs in a relatively high percentage of cases. In a series of thirteen dogs, leak of the anastomosis developed in only four, and here a cutting needle was employed. Seven of the thirteen functioned well; the remaining two died of postoperative pneumonia.

In other series, variations in technique were tested and the following conclusions were made:

1. Tension on the suture line of the anastomosis is one of the major causes of its failure to hold.

2. Postoperative mediastinitis and pleuritis due to contamination at operation can be minimized by careful walling-off about the field of anastomosis and by performing an end-to-side rather than end-to-end union, whether or not a portion of the cardia is resected. This is made between the upper cut end of the esophagus and the fundus of the stomach.

3. Interrupted two-layer linen suture technique was the one of choice, no stenosis of the anastomosis resulting from its use. Much stenosis followed the employment of a continuous suture in two cases.

4. Trauma of the vagi should be avoided during mobilization of the esophagus, since postoperative vomiting was much more noticeable when this occurred.

5. Mobilization should include only that portion of the esophagus to be resected, since the blood supply is likely to be interfered with by this procedure and lead to necrosis of the cut end of the esophagus, with resultant leak of the anastomosis.

6. A two-stage resection of the lower thoracic esophagus, with reunion of the esophagus and stomach, may be advisable in some clinical cases. In our experiments less esophagus could be safely resected when the two-stage operation was employed; the granulation tissue and adhesions reduced considerably the pliability of the tissues which interfered materially in performing the anastomosis without production of tension.

Resection of all or a part of the thoracic esophagus without establishing the continuity of the alimentary tract was not well-tolerated in our experience.

High resections were more successful than low ones because of less peristaltic action on the upper blind esophageal stump.

We wish to thank Leo Hrdina, Fred de Peyster, and William Johnson for technical assistance.

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CARCINOMA OF THE LOWER THORACIC ESOPHAGUS*

Report of a Successful Resection and Esophagogastrostomy

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SINCE Torek's successful resection of the thoracic esophagus for carcinoma in 1913,[1] thirty additional cases with involvement of the thoracic or abdominal esophagus have been reported by thirteen authors. Of these, seventeen were reported during the past three years, and only one (Torek's) is known to have survived five years or longer. Evidence of recent interest in the surgical treatment of this condition is both timely and deserving, since several years of trial of radium and intensive roentgen therapy has resulted in almost complete failure to obtain a permanent cure. A report by Watson in 1936 included the results in 666 patients receiving deep x-ray therapy at the Cancer Memorial Hospital in New York City. Of sixty-eight patients receiving the most recent advantages of this therapy, thirty-three were alive at the time of the report, eight, for one year and two, for two years. Of the remainder treated earlier, the average length of life was only 4.8 months.

A variety of factors have contributed to the delayed advancement in the treatment of this condition. The insidious nature of its onset with almost complete lack of symptoms in a large percentage of cases, until either considerable direct extension or distant metastasis has occurred, contributes largely to the high mortality. The first manifestations of the tumor, including dysphagia and very gradual loss of weight and strength, are usually overlooked or discounted by both the patient and the physician until a far-advanced stage of the lesion has been reached.

Another factor of considerable importance is the age of the patient. In a series of 107 patients reported by Graham and Ballon,[2] 85 per cent were more than 50 years of age and 39 per cent were more than 60 years of age. In general, this adds materially to the inanition and cachexia accompanying the tumor and the high mortality attending operative therapy. Thus, definite progress in the solution of this problem is dependent upon the realization of its frequency and the recognition of its early symptoms by the general practitioner and the laity.

A review of the literature reveals a variety of factors contributing to the failure of operative therapy. Infections of the mediastinum and pleural cavity are probably the most frequent complications and are

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TABLE I

SUCCESSFUL ESOPHAGEAL RESECTIONS FOR CARCINOMA

AUTHOR	CASES AND YEAR	TYPE OF OPERATION AND LOCATION OF TUMOR	LENGTH OF SURVIVAL	CAUSE OF DEATH
1. Voelker	1 1907	Abdominal with esophagogastrostomy (carcinoma of cardia)	? months	Metastases
2. Kümmel	2 1909 1910	Abdominal with esophagogastrostomy (carcinoma of cardia)	? months	Metastases
3. Torek	1 1913	Thoracocervical	13 years	Died of pneumonia
4. Zaijer	4 1913	Abdominothoracic (abdominal esophagus, first successful case)	Few months	Metastases
5. Brun	1 1913	Abdominal (abdominal esophagus)	? months	Metastases
6. Bircher	1 1918	Abdominal (abdominal esophagus)	Well 18 months postoperative	Metastases
7. Gohrbandt	1 1921	Abdominal (abdominal esophagus)	6 months	Intercurrent disease
8. Lilienthal	1 1921	Extrapleural. Thoracic reunion with skin flap	16 months	Metastases
9. Hedblom	1 1922	Abdominothoracic (abdominal esophagus)	Few months	Suicide
10. Küttner	1 1923	Abdominal (abdominal esophagus)	?	Metastases
11. Eggars	2 1925	Thoracocervical	6.5 months 18 months	Metastases
12. Turner	1 1931	Tunneling. Esophagus pulled down. Abdominal	19 months	Metastases
13. Ohsawa	11 1934	1—Exteriorization of thoracic esophagus 8—Esophagogastrostomy 2—Esophagojejunostomy (carcinoma of cardia and lower esophagus)	Not known	Not known
14. King	2 1936	Thoracocervical	One well, 11 mo. postoperative	
15. Fischer	1 1936	Tunneling Abdominocervical	Well 6 months postoperative	
16. Edwards and Lee	1 1936	Thoracocervical	10 months	Metastases
17. Brunn	1 1937	Thoracocervical	Well 8 months postoperative	
18. Garlock	3 1938	Thoracocervical	Well 18 months postoperative Well 11½ months postoperative Well 2½ weeks	

difficult to prevent. Because of the poor preoperative condition of the patient there is always danger of a postoperative pneumonia. Shock, hemorrhage, and postoperative pneumothorax have been given as the causes of death in some cases.

The above factors are obviously ample reason for the necessity of a very careful preoperative preparation of the patient. Fluids administered by mouth or parenterally and blood transfusions will aid materially in enabling a patient to successfully undergo an operation.

The choice of anesthesia is most important. In recent years great stress has been placed by some on the necessity of intratracheal anesthesia for intrathoracic operations. The importance of this type of anesthesia in some instances is not to be denied. It also has undoubtedly given surgeons a sense of security in carrying out intrathoracic operations. It has long since been learned, however, that most intrathoracic operations may be performed, and some with greater ease, under simple mask gas-oxygen inhalation anesthesia, the pressure obtained thereby being ample for maintaining inflation of the lungs for the necessary gas exchange. It also allows sufficient collapse of the lung to give adequate exposure for carrying out the operative procedures. Ohsawa[14] has emphasized the value of free open thoracotomy for operations on the thoracic esophagus.

The postoperative management should include maintenance of adequate water and mineral balance. Blood transfusions as a routine will help to prevent shock and hasten convalescence. Continuous siphon drainage applied to a stab wound drain of the pleural cavity will not only prevent accumulation of exudate, but will maintain the lungs in complete expansion, both of which are requisites for rapid healing and a smooth postoperative course.

In an accompanying communication experiments are described in which a segment of thoracic esophagus was resected, followed by anastomosis of the esophagus to the stomach.

Several methods of approach were tried, and one through the lower left chest wall was found to be the most desirable. In some animals the diaphragm was opened at the esophageal hiatus, the esophagus and stomach were mobilized, and 2.5 cm. of cardia and 5 cm. of esophagus were resected. The stomach and esophagus were then reunited with a two-row interrupted suture of linen. Leakage and infection occurred less frequently where the cardiac opening was closed, and an end-to-side anastomosis was made between the esophagus and fundus of the stomach. In some animals a 5 cm. segment of the lower esophagus was resected without mobilization of the esophagus at the hiatus. The lower cut end was ligated and inverted with a purse-string suture. The diaphragm was then opened at the dome, and the fundus of the stomach

brought through for the anastomosis. In all cases the diaphragm was made secure about the stomach, which remained in the thorax by interrupted linen sutures. Careful asepsis was practiced, and avoidance of tension on the suture line was found to be one of the major factors in the success of the operation.

The high degree of success attending these operations in dogs determined us to attempt a similar procedure in a patient with carcinoma of the thoracic esophagus. This was performed by one of us (D. B. P.) on January 26, the patient having an entirely uneventful convalescence.

Fig. 1.—X-ray following ingestion of barium showing defect in the lower esophagus. There is no definite evidence of involvement of the stomach.

CASE REPORT

Mrs. C. J., 53 years old, was admitted to the hospital on Jan. 22, 1938. She complained of difficulty in swallowing, of feeling weak and tired most of the time, and stated that she lost 8 or 10 pounds in weight during the three months before admission. Previous to this time she had not been especially strong for several years. About three months before admission food began to stick "down near her stomach" and would go no further. At times solid food was easier to swallow than liquids, although usually there was no difference. Sometimes in order to relieve herself of the "lump near her stomach" she would vomit, and the vomitus contained recently eaten food and mucus; but at no time was blood observed. Breakfast

was her best meal, little food being taken at any other time during the day. There was no history of pain either swallowing or at any other time.

Physical examination revealed a well-developed but fairly thin and fragile individual, not appearing acutely ill. Her weight on admission was 37.5 kg. Examination of the head and neck was negative. The lymph nodes in the cervical and axillary regions were normal. The blood pressure was 140 systolic and 74 diastolic. Her pulse was regular in force and rhythm. Examination of the chest and abdomen revealed no abnormal findings.

Examination of the blood revealed W.B.C., 6,920; R.B.C., 3.11, and Hb. 59 per cent. The Wassermann and Kahn tests were negative. Urine examination revealed no abnormalities.

X-ray examination following ingestion of barium revealed an abrupt narrowing of the esophagus beginning at a point approximately 6 cm. above the junction of

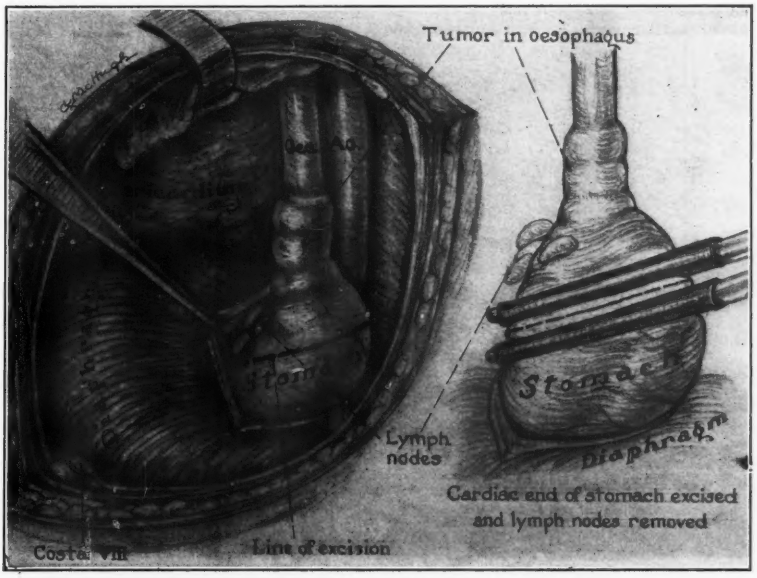

Fig. 2.—The eighth left rib has been resected and the thoracic cavity opened along this rib bed. The esophagus and stomach have been mobilized following enlargement of the esophageal hiatus.

the esophagus and stomach. There was no dilatation above this point. The normal rugae within the narrow portion were obliterated. The canal was irregular. The appearance of the cardiac end of the stomach was fairly normal (Fig. 1). A diagnosis was made of carcinoma involving the lower 6 cm. of the esophagus, with questionable involvement of the cardiac end of the stomach.

Preoperative Preparation.—The patient was given a transfusion of 550 c.c. of citrated blood on the day of admission. Following the transfusion the R.B.C. became 4.40 and the Hb. was raised to 80 per cent. Intravenous saline solution alternating with intravenous 5 per cent dextrose solution was administered over a period of three days preceding operation. During this time the patient was kept on a high caloric liquid diet. The operation was performed on January 26; the resection of 3 inches of the lower esophagus and 1 inch of the cardiac end of the stomach was followed by end-to-side anastomosis of the esophagus to the fundus of

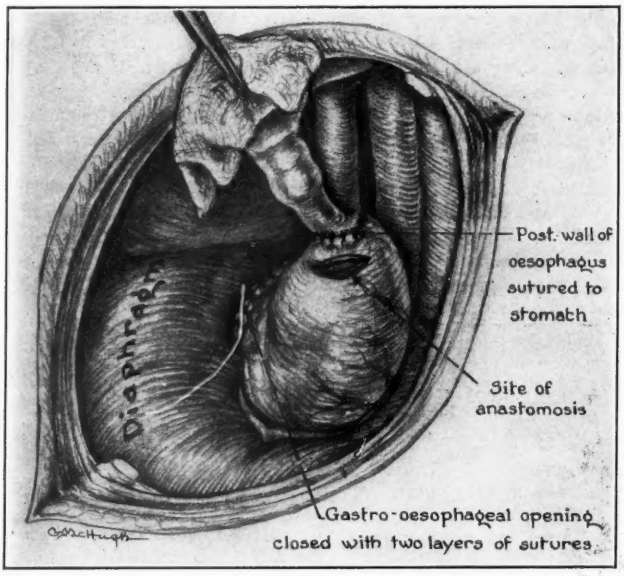
Diaphragm
Post. wall of oesophagus sutured to stomach
Site of anastomosis
Gastro-oesophageal opening closed with two layers of sutures

Fig. 3.—The stomach end of the resection has been closed by a double row of sutures. The first row of interrupted sutures may be seen on the posterior wall of the esophagus.

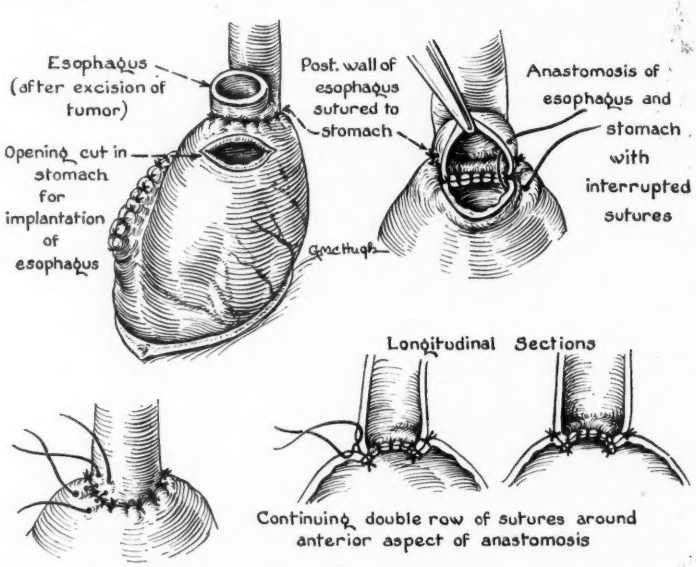
Esophagus (after excision of tumor)
Opening cut in stomach for implantation of esophagus
Post. wall of esophagus sutured to stomach
Anastomosis of esophagus and stomach with interrupted sutures
Longitudinal Sections
Continuing double row of sutures around anterior aspect of anastomosis

Fig. 4.—Detailed illustration showing method of application of sutures.

the stomach. A gastrostomy with a mushroom catheter was made, the catheter being carried out through a stab wound of the abdominal wall.

Technique.—The patient was given ⅙ gr. of morphine as preoperative medication. Ethylene-oxygen mask inhalation anesthesia was used throughout the operation. As the operation was begun, intravenous normal saline solution administration was started, and 500 c.c. of blood were added to the 500 c.c. of saline solution during the surgical procedure. The left chest was opened through an incision along the course of the eighth rib, following the subperiosteal resection of almost the entire length of that rib. Upon opening the pleural cavity, the lung was found free, except for a very slight adhesion near the terminal esophagus. A hard mass was palpable in the terminal 2½ inches of the thoracic esophagus. No enlarged lymph nodes were palpable in the mediastinum. The diaphragm was paralyzed by crushing the phrenic nerve with a hemostat. The diaphragm was incised about 2 inches away from the esophageal hiatus, and the incision was carried to the hiatus, following which the esophagus and cardiac end of the stomach were completely mobilized. The esophagus was then freed upward for a distance of 4 or 5 inches. On palpation intraabdominally, the esophageal mass extended fully 1 inch beneath the diaphragm. There were a few lymph nodes up to 1 cm. in diameter extending down to the

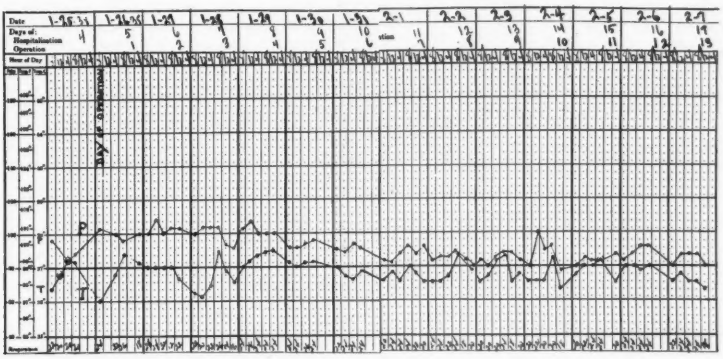

Fig. 5.—Temperature chart showing very mild postoperative course.

gastric artery on the lesser curvature (Fig. 2). One of these was definitely involved by metastasis. After ligation of the gastric artery, the stomach was pulled upward, and this mass of nodes was reflected upward. Intestinal clamps were then placed on the stomach about 2 inches from the proximal end, and the stomach was divided, the distal end being closed by two layers of continuous Czerny-Lembert sutures of linen. The esophagus was freed for a distance of 2 inches above the tumor. A portion of the fundus of the stomach was then anchored to its posterior wall by five interrupted sutures of linen (Fig. 3). The esophagus was then cut across and the stomach opened, with an intestinal clamp applied. An inner layer of through-and-through interrupted linen sutures was then introduced, and the anastomosis completed by burying this anteriorly with a row of external interrupted linen sutures (Fig. 4). There was very little soiling throughout the period of anastomosis. A mushroom catheter was introduced through an opening made in the anterior wall of the stomach and made secure with two purse-string sutures. It was then carried out through a stab wound in the abdominal wall. The diaphragm could not be pulled upward above the level of the anastomosis. It was then sutured to the stomach about 2 inches below the site of anastomosis with interrupted linen sutures, thus shutting off the thorax from the abdomen. Great care was taken that no tension

was placed on the gastroesophageal suture line. A pezzar catheter was introduced into the thoracic cavity through a stab wound in the ninth intercostal space, for closed drainage following the operation. The edges of the chest wall were then approximated with three catgut tension sutures placed about the seventh and ninth ribs. A continuous 0-40 day catgut suture was used for the pleura and intercostal muscles, and a similar one was used for the subcutaneous muscles and fascia. The skin was closed with silk.

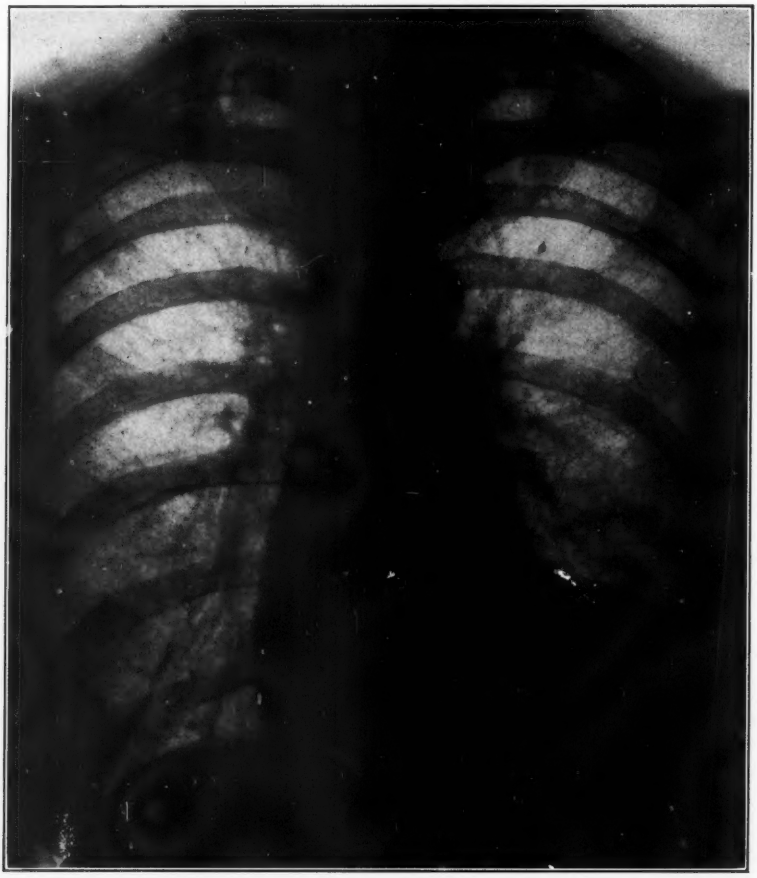

Fig. 6.—X-ray picture of chest taken fifteen days following operation. Note bubble of gas at the apex of the right heart representing the portion of the stomach remaining in the chest.

As soon as the operation was completed, obliteration of the pneumothorax was obtained by aspiration of the remaining air through the drainage tube. Continuous suction by means of a double Wangensteen apparatus applied to the drainage tube was carried out for one week following operation. The pulse and blood pressure remained fairly constant throughout the operation, neither one being alarmingly abnormal at any time. The patient was returned to her room conscious and in good

condition, and 1,500 c.c. of normal saline solution were administered beneath the skin. The only complaints were of fullness in the region of the epigastrium and dryness of the mouth.

Postoperative Course.—The postoperative course of the patient was very mild and uncomplicated (Fig. 5). At no time was the temperature above 99.5° F., and following the first few days it remained below 98.6°. At twelve hour intervals for seven days, 1,500 c.c. of Ringer's solution by hypodermoclysis and 1,500 c.c. 5 per cent dextrose solution in distilled water, intravenously, were administered alternately. There was a small amount of regurgitation of bile on the first postoperative day. The patient complained of some pain in the left shoulder on breathing and of a generalized weakness. This persisted for about ten days. There was very little

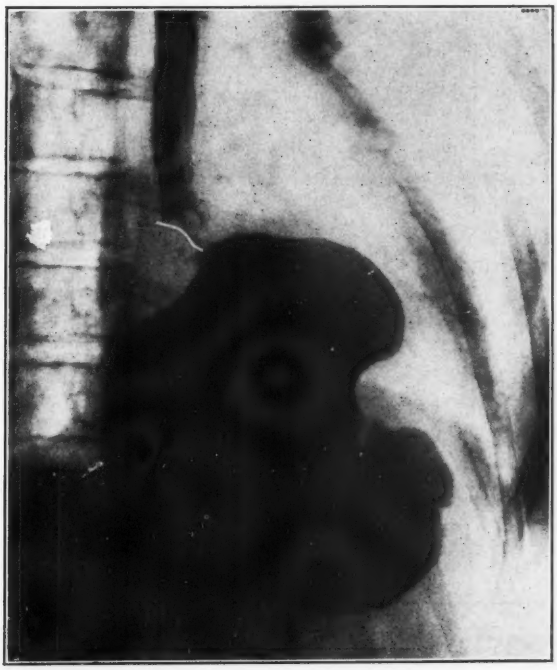

Fig. 7.—X-ray picture following ingestion of barium showing the site of the anastomosis and the elevation of the stomach above the diaphragm. Fluoroscopy revealed no evidence of obstruction at this time.

drainage from the pleural cavity, a total of 50 c.c. of a serosanguineous exudate being obtained during the entire postoperative course. The thoracic catheter was left in place until an x-ray picture was taken of the chest on the seventh postoperative day. This revealed the lungs fully expanded with no air or fluid demonstrable in the pleural cavities, and the catheter was removed at that time. The wound healed by primary intention, the stitches being removed on the seventh postoperative day. The patient was fed through the gastrostomy tube beginning with the seventh postoperative day. Nothing was given by mouth until two weeks following the operation. She was then allowed up. At the end of seventeen days she was taking most of her diet by mouth, and although she complained of some fullness after eating, by de-

A.

B.

Fig. 8*A* and *B*.—Photographs of specimen before and after opening the esophagus. Note elongated tumor with rounded ends reaching almost to either end of the specimen.

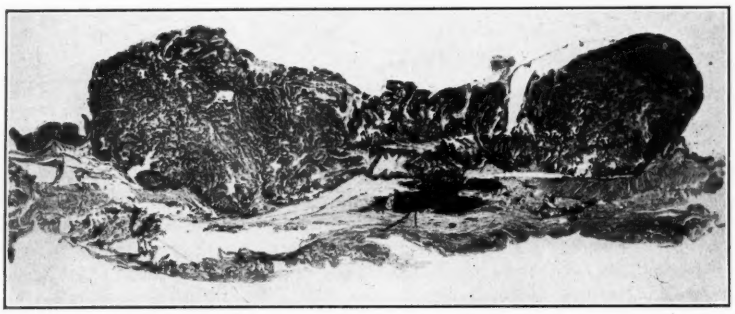

Fig. 9.—Microscopic section of tumor showing involvement of the entire thickness of the esophageal wall at its lowermost portion. Note normal esophageal mucosa at the upper limit and evidence of the tumor slightly beneath the gastric mucosa at its lower limit. (×3)

creasing the intake at one time and increasing the number of feedings, this complaint was practically eliminated (Fig. 6). She was discharged from the hospital on February 19, 1938, the twenty-fifth postoperative day, her case to be followed in the outpatient clinic.

She was seen again on February 28, at which time her main complaint was of some fullness in the stomach after eating. She had gained considerable strength. She was again seen on March 14, at which time fluoroscopy during the ingestion of barium revealed unobstructed passage through the anastomosis (Fig. 7). She complained of regurgitating considerable amounts of mucus during or following some of her feedings.

Examination of Specimen.—The gross specimen presented an elongated, ovoidal-shaped tumor mass measuring about 3 inches in length and ¾ inches in diameter, involving the esophagus to its junction with the stomach. It was quite firm to the touch (Fig. 8*A* and *B*). Microscopic sections revealed a squamous cell carcinoma exhibiting fairly numerous keratohyalin pearl formations. At the cardiac end it projected slightly beneath the gastric mucosa. The tumor had extended through

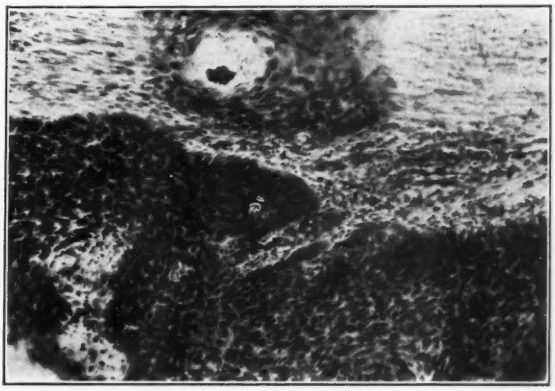

Fig. 10.—High power photograph of tumor shown in Fig. 9, revealing typical squamous cell carcinoma with keratohyalin pearl formation.

the muscular layer of the esophagus at its lower end (Figs. 9 and 10). A microscopic section of one of the glands removed from the lesser curvature of the stomach revealed metastases.

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UPPER ESOPHAGOSTOMY

Its Indications and Uses

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BY UPPER esophagostomy is meant the establishment of a communication between the upper portion of the esophagus and the surface of the skin.

It may be intended to establish communication in a downward direction with the stomach, in case the upper end is obstructed or had to be sacrificed for the removal of a tumor, or in an upward direction to permit swallowing, in patients having an obstruction in the lower portion.

In the former case, the indication for operation is usually the presence of a carcinoma affecting the upper end of the esophagus. Experience has shown that the growth usually involves not only the upper esophagus, but that it has spread into the hypopharynx and not infrequently invades also the larynx. As a matter of fact, when the growth has reached such dimensions it is impossible to state where it had its origin. In order to bring about a cure it is therefore necessary to sacrifice the larynx and pharynx together with the upper end of the esophagus.

Such operations have been performed successfully, and patients have completely recovered. After doing a preliminary gastrostomy one may pursue one of two courses, either to rely on permanent gastrostomy feedings or to attempt reconstruction of the pharynx later. If one is satisfied from the beginning to rely on permanent gastrostomy feeding, the best way to handle the lower esophagus stump is to ligate it with silk, cauterize it, and then allow it to recede into the mediastinum.

On the other hand, if one plans to do a reconstruction of the pharynx later, it is necessary to maintain patency of the esophagus. Fortunately, the extent of esophageal involvement in the type of case under consideration is usually limited to its extreme upper end, and the remaining lower esophagus is sufficiently long to permit its attachment to the skin flaps just above and behind the tracheostoma.

In all such cases the esophagostomy is one of necessity and is unavoidable if one desires to attempt reconstruction later, at least, if one does not want to deprive the patient of this hope. Successful resections of the larynx and pharynx with the upper end of the esophagus, and later plastic reconstruction of the pharynx with the aid of skin flaps, have repeatedly been performed. The names of Gluck,[1] von Hacker,[2] and

Read before the Twenty-first Annual Meeting of the American Association for Thoracic Surgery at Atlanta, Ga., April 4, 5, and 6, 1938.

Lotheissen[3] are linked with the development of these extensive operative procedures. Cases of this type present themselves infrequently, and it is difficult, therefore, for anyone to gain an extensive experience. Unfortunately, most of these cases are recognized too late for permanent cure, and although patients may recover from the operation, they do not live sufficiently long to have a reconstruction of the pharynx done. In the meantime they have to depend on gastrostomy feedings. We presented a case of this type before the New York Surgical Society in 1925.[4]

The patient, Mrs. P. G., 30 years of age, had a carcinoma of the esophagus and larynx, with symptoms dating back about six months. She had one child, 4 years old, and at the time of admission was pregnant about four months. She was a healthy looking young woman and had no evidence of constitutional disease. Her breath was putrid and she seemed distressed by the inability to swallow her own saliva. Biopsy showed squamous cell carcinoma. A gastrostomy was done on the day after admission under local anesthesia. It was planned to do the principal operation in two stages, to avoid mediastinitis. The first stage was done ten days after the gastrostomy as follows:

A transverse incision was made at the level of the hyoid bone from one sternocleidomastoid muscle to the other. A vertical median incision was added, reaching to the suprasternal notch. The sternocleido and sternohyoid muscles were retracted, and the sternothyroids divided. The thyroid gland was likewise divided, and the lobes displaced laterally. The trachea was then completely freed down to behind the sternum. The esophagus was also freed upward and downward. A hard tumor was felt in its upper end, extending about ¾ inch below the cricoid cartilage and upward into the pharynx. It seemed to involve the entire circumference and apparently extended onto the posterior wall of the larynx. It was not perforated. Only one enlarged gland was found and excised for examination. After the pharynx had been separated from the spine, iodoform gauze strips were inserted behind it and the esophagus, between the esophagus and the trachea, and also surrounding the trachea and larynx. The skin incision was closed, except about 1 inch in the lower median wound, which was left open for access to the trachea should a tracheotomy become necessary.

There was no difficulty after the operation except a little respiratory distress for the first day or two, probably due to pressure of the tampons. The wound healed by primary union. At times the patient was able to swallow small quantities of water. Her greatest distress was due to inability to swallow saliva and tumor secretion and to the difficulty in expelling them through the mouth.

In August, 1924, a week after the first stage, the final radical operation was done, again under colonic anesthesia. The incisions were reopened, and the tampons removed. The wound was perfectly clean. The trachea was divided between the first and second tracheal rings, cocainized, a tampon inserted into the upper end, and the lower end drawn forward and at once fastened into the lower angle of the wound by means of a few silk sutures. The esophagus was divided about ½ inch below the tumor, which was about 1¼ inches below the level of the cricoid. This left a rather short esophageal stump which could be kept in the field only with considerable traction. By drawing the larynx and pharynx upward and forward it was possible to free them without difficulty as far as the hyoid bone. The thyrohyoid membrane was divided, and the incision completely carried around the pharynx at this level. The specimen was removed (Fig. 1). The sternohyoid muscles were divided because they

projected forward and interfered with proper closure. The anterior margin of the pharynx was united to the skin edge under the chin, while the posterior margin was sutured to the upper border of the skin flaps. The latter were then partly closed in the median line, leaving an opening for the exit of tampons. Below, two small incisions were made in the margin of each skin flap, thus forming a bridge

Fig. 1.—Larynx and upper end of esophagus with extensive carcinoma.

Fig. 2.—Patient after removal of larynx, pharynx, and upper esophagus. Nodule shown in left lobe of thyroid which eventually caused fatal outcome.

about ¾ inch wide, which was interposed between the tracheal opening and the esophageal opening, and both tubes were then sutured to the skin margins by interrupted silk sutures. One iodoform gauze tampon had been placed behind the esophagus, and two smaller ones upward behind the stump of the pharynx. Their free ends were brought out through the opening left in the median line, together

with two split tube drains. A dry dressing was applied, and moist gauze placed over the tracheal opening. The patient was returned to bed with the foot end elevated.

The convalescence was very smooth. She was delivered of a normal baby Dec. 12, 1924. During the last weeks of her pregnancy she developed a metastatic nodule in the left lobe of the thyroid, which broke down after treatment with radiation. While she was at the hospital for the accouchement this fluctuating area was incised. The wound never completely healed, and during the night of Jan. 21, 1925, the patient suddenly had a hemorrhage from this wound, probably due to erosion of a vessel, and died of aspiration of her own blood into the tracheotomy opening.

Torek[5] had a patient in 1926 who recovered from the operation but also did not live sufficiently long to have the reconstruction of the pharynx performed.

Fischer,[6] however, completed the operation in one of his cases, and the patient was able to swallow quite normally. Unfortunately, the patient died on the operating table a year later while being operated on for massive uncontrollable gastric hemorrhage. The cause of bleeding was found to have been a large ulcer of the posterior wall, with a branch of the splenic artery responsible for the fatal outcome. There was no evidence of metastases.

If the patient is seen earlier, and especially if there is no apparent involvement of the larynx, one may hesitate to perform such an extensive mutilating operation, being satisfied with a less radical one, frequently, however, at the cost of a recurrence and an eventual fatal outcome. We had such a case some years ago in which it was possible to save the larynx. Instead of doing a complete circular division of the esophagus, the tumor only was removed, leaving normal mucosa anteriorly. Aside from the technical difficulties encountered in working in the narrow space of the hypopharynx, which carries with it the danger of an incomplete operation, the result from a functional standpoint was never satisfactory. There was no interference with the voice, but normal deglutition was not re-established. In spite of the maintenance of a lateral esophagostomy and frequent attempts at dilatation of the hypopharynx, the patient was unable to swallow. We attributed this to the sacrifice of a large portion of the constrictor muscles, with secondary contraction of the hypopharynx. The patient died about five months after operation, probably of metastases.

Judging from this experience as well as a study of the literature, it appears advisable not to be satisfied with incomplete operations when dealing with carcinoma of this region. The operation must be planned on a large scale and executed with the mind on wide excision of the primary lesion as well as the probable lymphatic extensions.

All these operations are extensive and lead to disability involving loss of voice and frequently loss of power to swallow, though the latter may in suitable cases be restored by a plastic reconstruction of the pharynx from the skin of the neck.

For these reasons the questions arise: should one continue along this line of surgery or, in this type of case, does modern radiation treatment offer more than surgery?

In cases in which the carcinomatous involvement is definitely limited to the upper end of the esophagus and permits removal with a safe margin of normal tissue, the problem is simplified in that the larynx and pharynx may be saved. However, other problems concerned with deglutition may present themselves and tax the patience of both the surgeon and the patient.

Regardless of where the tumor is situated, it is best to perform a gastrostomy and then to divide the esophagus circularly well below the tumor, ligate and cauterize the lower stump, and allow it to recede into the mediastinum. The upper end with the tumor may be handled in one of two ways. In case there is a portion of uninvolved esophagus above the tumor sufficiently long to be utilized, it may be brought out at the neck and later used for connection with the gastrostomy by means of a rubber esophagus, thus permitting deglutition; or, one may attempt reconstruction of the esophagus with the aid of a skin tube or portion of bowel. Usually, however, there is not a sufficiently long portion of esophagus remaining above the tumor to make this possible. In such a case the pharynx will become closed off permanently, or perhaps a small mucous fistula forms, which will permit escape of saliva but will be useless for restoration of the act of swallowing. We had such a case somewhat more than a year ago.

Mrs. T. L., 32 years of age, was referred to us with the established diagnosis of squamous carcinoma of the upper esophagus. The extent of the disease had not been definitely discovered, but it had been determined that the tumor did not enter the hypopharynx.

The patient's chief complaint was inability to swallow solid food. The symptoms began about six months previously with a feeling of sore throat. Gradually difficulty in swallowing developed, particularly hot food, but she did not suffer sufficiently to consult a physician until a month before admission. There had been some loss of weight, from 120 to 109 pounds. She had continued to take fluid and soft food in sufficient quantity, without pain except a little in the ears.

There was nothing in her past history to throw light on the present condition. She was married and had one child 2½ years old.

Her general appearance was excellent, and it was difficult to believe that she had such a serious condition. The diagnosis made at another institution was verified at our hospital roentgenographically as well as pathologically.

The examination of the throat was negative, but a friable tumor mass was seen in the upper esophagus, practically filling it. It seemed to arise mostly from the anterior wall. A biopsy was done. It was deemed inadvisable to attempt passage of the esophagoscope. The larynx was freely movable and not painful. There was no cervical lymph node enlargement. Operation was indicated and was performed Mar. 3, 1937.

A 5 inch incision was made along the anterior border of the left sternocleidomastoid muscle. The skin and muscles were retracted laterally, and the thyroid gland

exposed. Its inferior vessels were doubly ligated and divided, permitting the gland to be displaced upward. By blunt dissection the trachea and upper esophagus were now freed. A hard tumor was felt in the esophagus, which had apparently not invaded the surrounding structures, although all the coats seemed to be involved, especially on the right side. The exposed portion was freed posteriorly and separated from the trachea anteriorly without much difficulty. A tape was now passed around it and by gentle traction and blunt dissection it was freed downward beyond the tumor as far as the middle finger could reach. By applying a pedicle clamp below the tumor and continuing traction, a heavy silk ligature was placed well down, and the esophagus then divided with an electrocautery. The stump was allowed to drop back. The upper end with the tumor was now freed upward all the way to the hypopharynx and larynx. Although it was known from previous examinations that the tumor did not extend into the hypopharynx it seemed to

Fig. 3. Fig. 4.

Figs. 3 and 4.—Carcinomatous lesion of upper esophagus.

extend right up to it, and the possibility of removing it completely did not look very promising. It was deemed advisable to interrupt the operation at this point and not to remove the tumor. The entire upper esophagus was therefore brought out at the neck in order to permit adhesions to form before removing the specimen, similar to the procedure used in a two-stage operation for diverticulum.

A strip of rubber dam was inserted down into the mediastinum to the lower esophagus stump. The left lobe of the thyroid was found to be in the way of the upper esophagus stump and was therefore removed. The ribbon muscles were partly united below. At the site of emergence of the esophagus, the skin was sutured well down into the depth in order to favor its attachment above the involved portion of esophagus and to help form a deep funnel-like depression which might later be used for reconstruction of an esophagus from a skin tube. After applying vaseline dressing to the wound, the stump was opened to permit exit of secretions.

A Janeway gastrostomy was now done through the upper end of the left rectus muscle.

The convalescence was very satisfactory. The gastrostomy functioned well. Part of the projecting esophagus stump with the tumor, about 3 inches in length, sloughed away, but the remaining stump looked clean. The lower part of the wound healed promptly after the mediastinal drain had been removed. At no time was there any secretion from this region.

Sixteen days after the original operation on Mar. 19, 1937, the second stage was performed as follows:

The skin around the esophagus stump with that portion of the tumor which had not sloughed away since the first stage was freed and retracted. The esophagus was then dissected upward to the hypopharynx and divided with the electrocautery just above the tumor. The division was made entirely in normal tissue, although what seemed to be an implantation in the wall reached almost to the cut edge. However, there was no ulceration present here. In order to be absolutely safe, another small piece of anterior as well as posterior wall was removed, which carried the operation up into the hypopharynx. These pieces were marked for special examination.

There was no evidence of carcinoma having extended into the surrounding tissue. It was deemed inadvisable to attempt any plastic procedure at this time. Bleeding points were therefore controlled, and the wound was dressed with vaseline strips. Apparently about 4 or 4½ inches of esophagus had been removed in all.

The postoperative course presented serious problems for consideration. It had been hoped to be able to establish an epithelialized canal from the hypopharynx to the skin, to serve for connection with the gastrostomy and permit deglutition. After the packing was removed from the wound, however, there was rapid contraction of the opening, and swallowing was difficult.

Two alternatives presented themselves:

1. To allow the wound to close; this would probably mean permanently. It would prove satisfactory by doing away with a discharging neck wound. It would condemn the patient, however, to permanent gastrostomy feeding. It further brought up the question as to whether or not there is danger of aspiration with a closed hypopharynx, especially if the patient should contract a nasopharyngitis with its increased secretion. It was considered possible that normal secretion of saliva and mucus would gradually diminish, as the glands would atrophy somewhat from lack of use.

2. To reopen the hypopharynx by passing an instrument from above and leaving a small tube in place. This might gradually lead to epithelialization of the tract by epithelium growing downward from the hypopharynx and upward from the skin. If successful, one might later aid such epithelialization by inserting a skin flap and eventually perform a reconstruction of the esophagus from a skin tube.

These problems were discussed with Dr. Oberrender of our Otolaryngological Department, and it was decided to attempt keeping the canal open. A duodenal type tube, brought out through the nose, was used in the beginning and was kept in place for several days. It annoyed the patient so much that it had to be discontinued. While withdrawing it we attached a flat mushroom catheter to its lower end and drew this into place. The flange of the catheter came to lie in the hypopharynx, while the projecting lower end was cut off flush with the skin. The patient was encouraged to drink frequently in order to restore the swallowing function and to aid in keeping the canal open. The presence of the catheter against the posterior surface of the larynx annoyed her considerably and produced sore throat as well as pain in the

ears. Nevertheless, the patient cooperated well and was discharged with the catheter in place. After about four weeks the tube had to be discontinued, and, after discussing the problem with the patient, she chose to have the canal permitted to close in order to do away with dressings and further attempts at instrumentation. She was well able to take care of her gastrostomy feedings, was satisfied with them, and was gaining weight.

The canal has since been closed most of the time, though occasionally it opens and discharges some mucus.

In November, 1937, the patient noticed a swelling on the right side of the neck, which on examination was found to be a hard, deep-seated nodule behind the lower portion of the sternocleidomastoid. It seemed to be a metastatic lymph node.

Fig. 5.—Patient with rubber esophagus.

Operation was performed Nov. 20, 1937. A 4 inch supraclavicular incision was made. In order to gain the necessary access, the posterior portion of the sternocleidomastoid had to be divided close to the clavicle. The omohyoid was incorporated in the mass and had to be sacrified. The internal jugular vein was also closely adherent and seemed to be involved. It was therefore resected for a distance of 1 inch. The entire mass was then dissected off the brachial plexus, saving all other vital structures.

To our surprise the pathologic report was not carcinoma but chronic inflammation with necrosis. It was probably due to absorption from the fistulous tract.

There has been no further disturbance, and at present the patient is well except for the rather annoying expectoration of mucus.

Esophagostomy, having as its object a communication in an upward direction into the pharynx for the purpose of permitting deglutition, may be performed as part of the radical operation for relief of obstruction of the lower esophagus, or it may be performed as an independent operation in those cases in which removal of the malignant or benign stricture is not possible.

Attention was first directed to it by Torek's successful operation[5] of resection of the thoracic portion of the esophagus for carcinoma. A part of that procedure consists in bringing the esophagus out at the neck and implanting it under the skin of the chest wall. He used this stoma for connection with the gastrostomy by means of a rubber esophagus and thus made deglutition possible.

The principle announced by Torek of the advisability or rather necessity of bringing the esophagus out at the neck in order to avoid medi-

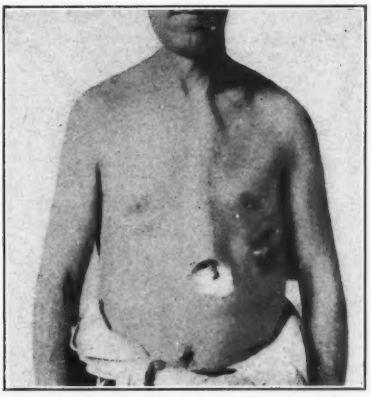

Fig. 6.—Patient with reconstructed esophagus.

astinal infection has proved of value in the hands of all those surgeons who attempt radical surgery of the esophagus.

The implantation of the upper esophageal stump, after resection of the lower portion, in order to form an esophagostoma for connection with the gastrostomy by means of a rubber esophagus, is equally applicable to benign and malignant lesions.

Instead of continuing a rubber esophagus, an artificial esophagus may be constructed from the skin of the chest wall, from a loop of gut, or even from the stomach itself, as described by several authors. Sometimes a combination of two methods answers this purpose best. Oehsner[7] reported such a reconstruction with the aid of a portion of jejunum and a skin tube of the chest wall.

We have performed a reconstruction after resection of the esophagus in which only skin of the chest wall was utilized, with a satisfactory re-

sult except that the connection between the skin tube and the gastrostomy has not been completed.[4]

Instead of doing Torek's operation in one stage, which is shocking and has a rather high mortality, the thought has been suggested of doing it in two stages. As proposed by Torek, the removal of the involved esophagus and the subsequent implantation of the remaining stump comes at the end of the intrathoracic part of the operation. By dividing the operation into two stages, the order is changed. Either as an independent operation, or, in patients in fair general condition, at

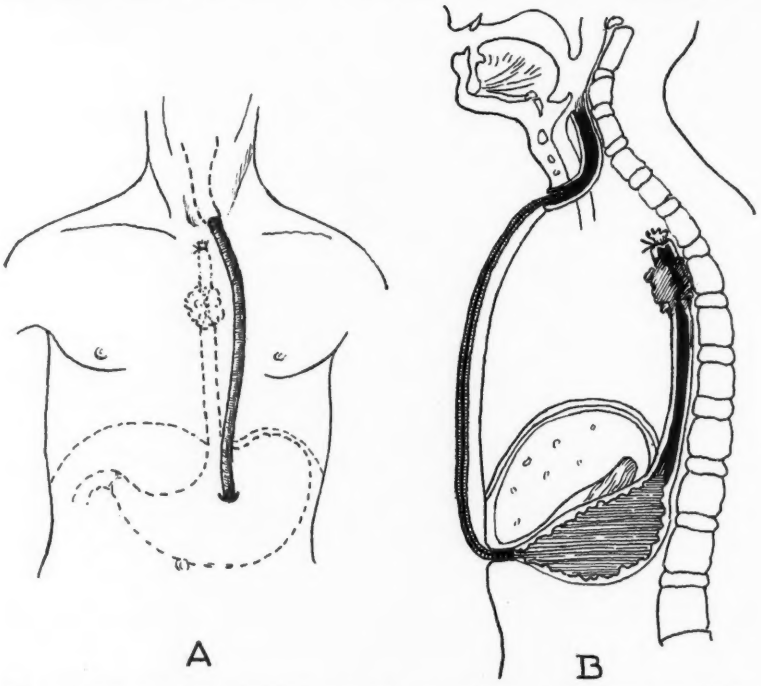

Fig. 7*A* and *B*.—Upper esophagostomy and gastrostomy. Intrathoracic carcinoma still in situ.

the time of the performance of the gastrostomy, an incision is made in the neck, as for exposure of an esophageal diverticulum. The esophagus is freed downward as far as possible and divided. The upper end is brought out at the neck and implanted to form an esophagostoma.

The intrathoracic operation is then later carried out as an independent procedure, with less shock and less possibility of contamination. We hope that this sequence will result in a greater percentage of successful results.

Prompted by the reluctance of patients and their families to have a gastrostomy performed for esophageal obstruction except as a last re-

sort, we have lately gone a step farther in the handling of these cases. The proposal to perform a gastrostomy is usually quite a shock to patients because it carries the implied suggestion that they will never swallow again. Even the gastrostomy itself is distasteful to them because they have to wear a tube. This latter objection has been largely overcome by doing a Janeway gastrostomy, which usually does not leak and which does not require the use of a tube or catheter except at mealtime. But the patients want more than that, they want to masticate, taste, and swallow food. To meet this desire the procedure of combining the gastrostomy with an upper esophagostomy, thus permitting deglutition with the aid of a rubber esophagus, has been considered and carried out. We have therefore lately begun to do an esophagostomy in all suitable cases of carcinoma of the thoracic portion of the esophagus, in conjunction with a gastrostomy, regardless of whether removal of the tumor is contemplated or not.

The method of procedure and the technique are best illustrated with an actual case.

Mr. J. H., 49 years of age, was referred to us with an established diagnosis of carcinoma of the thoracic portion of the esophagus. A gastrostomy had been done at another hospital. It was decided to attempt an esophagectomy in two stages. The first operation was done April 24, 1937. A 4 inch incision was made along the anterior border of the left sternocleidomastoid muscle. This was then retracted laterally together with the ribbon muscles and the vessels, exposing the thyroid gland. The inferior thyroid vessels were doubly ligated and divided to permit upward displacement of the gland. The esophagus was easily exposed and liberated, and a tape was passed around it for gentle traction and blunt dissection downward with the finger as far as possible. A heavy silk ligature was applied here, and a pedicle clamp just above it. The esophagus was then divided with a cautery, the lower stump dropped back, and the upper one brought out at the neck.

A rubber-dam drain was placed in the mediastinum. The muscles of the neck as well as the platysma were sutured around the projecting esophagus, which was allowed to emerge just above the sternoclavicular joint. The skin was closed with silk. After applying a vaseline dressing, the stump was opened at once to permit discharge of mucus, and the free margin was sutured to the skin with silk.

The convalescence was uneventful. The use of a rubber esophagus was started early and functioned well. The patient regained the initial loss of weight, so that the second stage of the operation could be performed about three weeks later, on May 17, 1937.

An incision was made along the entire left seventh intercostal space and carried upward posteriorly over the seventh, sixth, fifth and fourth ribs. The latter were divided, and the chest opened wide. The mediastinal pleura was incised from the lower margin of the arch of the aorta to the diaphragm. Two large lymph nodes were removed for diagnosis (reported metastatic carcinoma). The esophagus was liberated below, a tape passed around it, and it was then freed upward, partly by blunt, partly by sharp dissection. A hard, fixed tumor was found situated behind the arch of the aorta and extending about 1 inch below it. An attempt was made to mobilize it, but it was so firmly attached to the aorta as well as to the pedicle of the opposite lung, that there seemed to be no prospect of freeing it completely. An incision was now made above the arch of the aorta for the purpose of

aiding liberation from above, but this was also unsuccessful. The incision was then carried down along the left margin of the aorta, and two left intercostal arteries were ligated and divided. This allowed moderate mobilization of the aorta, but the tumor was so firmly adherent and seemed to involve the wall of the aorta to such a degree that extirpation was impossible. The attempt was therefore discontinued.

The pleural incisions were sutured with continuous plain catgut, and the chest wall was then closed with layer sutures. Closed drainage was established through the tenth intercostal space.

The convalescence was very satisfactory. Feeding with the aid of the rubber esophagus was resumed as soon as the patient had recovered from the postoperative reaction. He was discharged June 7, 1937, three weeks after operation. He was under the impression that the tumor had been removed, was cheerful, and happy to be able to masticate and swallow his food. He died Nov. 4, 1937, about five months after operation.

Combining an upper esophagostomy with a gastrostomy in patients having an obstruction of the thoracic portion of the esophagus has the following advantages. It allows normal mastication of food, gives the patient the pleasure of tasting food, which adds to his general well being, and permits fairly normal deglutition through a rubber esophagus. It has the additional advantage of aiding salivary digestion, and thereby aids in more rapid gain of weight than is usually possible with gastrostomy feedings alone.

Should the general condition of the patient later permit an attempt at radical transthoracic removal of the tumor, the operation will be shorter and less dangerous than if the entire procedure is carried out in one stage.

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DISCUSSION ON "CARCINOMA OF THE LOWER ESOPHAGUS," BY W. E. ADAMS AND D. B. PHEMISTER; AND "UPPER ESOPHAGOSTOMY," BY CARL EGGERS

DR. E. D. CHURCHILL, Boston, Mass.—May I ask Dr. Adams if he would feel justified, in a case of cancer at the extreme lower end of the esophagus, to start his surgical program by a thoracic incision, or whether he might feel as I do, that in the

majority of these cases it is advisable to do a laparotomy and gain some information as to the extent of the growth or metastases in the abdomen. I have had the experience of being unable to determine by x-ray pictures the presence of an extensive involvement of the cardiac end of the stomach or lymphatic metastases in the gastrohepatic omentum. Consequently, I believe that laparotomy should be done before undertaking the more extensive thoracic approach.

I have operated on eight or nine patients in whom the intraabdominal extent of the carcinoma precluded any later operation. A palliative gastrostomy may then be done. If the growth appears to be suitable for resection, a temporary jejunostomy can be performed, either to prepare a poor risk patient for the major procedure or to serve as an aid to postoperative feeding.

DR. RICHARD H. OVERHOLT, Brookline, Mass.—Dr. Adams should be congratulated on the report of a successful resection of the esophagus. Dr. Samuel Marshall and I have recently carried out a similar technique for carcinoma of the esophagus in two patients. A preliminary gastrostomy was not employed.

It would seem to me that there would be an advantage in not having a gastrostomy before the operation, for the stomach can be more readily mobilized. After the operation the anastomosis of the esophagus to the stomach in the thorax healed well and functioned properly in the first of our two patients.

The first patient, a 35-year-old man with a nine months' history of partial esophageal obstruction due to a carcinoma in the lower third, was operated on, had a fairly satisfactory convalescence, and is still living today. The second patient operated upon by such a technique died on the tenth postoperative day. The suture line was defective.

It seems to me that resection may be performed in more patients if, following clinical study, it has been shown that there is no definite evidence of an extension of the growth beyond its primary site, and that a thoracic exploration is made as the primary operation. We will be able to determine then whether or not there is mediastinal extension. The diaphragm can be opened and an exploration of the abdomen made, the liver palpated, and then, if there is no obvious extension of the growth, proceed with a primary excision and production of a thoracic stomach.

In the past, a great many patients have been explored abdominally by the general surgeon, and the low esophageal growth palpated by the exploring hand from below. In almost every instance when the case has been so managed the lesion has been considered inoperable and refused for resection because the general surgeon reported fixation at the hiatus. I believe it may be difficult to determine fixation of the growth by abdominal exploration and that resection will be done in more patients if the primary operation is done through the thoracic approach.

DR. CARL EGGERS, New York, N. Y.—A few years ago, in discussing the report of a case of carcinoma of the cardia presented before this Association by Dr. Decker, I reported a patient operated on by a method almost identical with that presented by Dr. Adams and Dr. Phemister. Our patient died on the tenth day. Post-mortem examination showed that he had died as the result of a localized mediastinal abscess. It was apparently not due to postoperative leakage but to soiling of the field at the time of operation.

The most interesting finding was that the esophagus, which is not covered with serosa, had healed firmly into the serosa-covered stomach wall. This observation has encouraged us very much in the belief that carcinoma situated at the lower end of the esophagus or at the cardia offers a better prospect for a satisfactory result than carcinoma situated at a higher level. Successful implantation and, there-

by, reconstruction of the entire mechanism of swallowing is possible. As indicated in Dr. Adams' case to all intent and purposes swallowing is normal. I want to congratulate him on his fine result.

DR. WILLIAM DEWITT ANDRUS, New York, N. Y.—I have been interested in this type of anastomosis for a great many years since Dr. R. T. Miller and I performed a series of experiments (in 1922) on dogs somewhat similar to these. Since that time I have been hoping to be able to find a case in which this operation could be performed, but I have had an experience similar to that of Dr. Churchill. We always do a laparotomy first and have been consistently disappointed in finding metastasis so extensive that the operation could not be successfully performed.

I should like to add two other points. First, the stenosis which Dr. Adams reports in the esophagogastrostomy is a very real thing, and I am not sure it is to be connected with the use of a continuous suture because we found it quite as often with interrupted sutures, although the method we used, in which we attempted to do an aseptic anastomosis by the use of the purse-string suture, may have contributed to this.

The other point is that the esophagus will heal well if sutured without tension, whether it be to the stomach or the esophagus itself, as it possesses a very adequate submucosa which will hold sutures quite satisfactorily.

DR. HARRY R. DECKER, Pittsburgh, Pa.—If one contemplates an anastomosing operation through the diaphragm, it is absolutely essential to have a free stomach, and I believe one is handicapped by a preliminary gastrostomy. A substitute for this, jejunostomy, I think answers that difficulty. The patient can be fed very well and brought into a better state of nutrition by a preliminary jejunostomy as well as by using the gastrostomy.

DR. HAROLD BRUNN, San Francisco, Calif.—We have all had experiences with carcinoma of the esophagus, most of which have been discouraging either because of the extent of the disease and inoperability or because infection occurred through some fault in technique.

Surgery in this region is extensive and shocking. About eight years ago I had an excellent example of such a case in a young man with carcinoma of the esophagus, fairly well localized near the cardia. In this case the tumor-bearing area was removed, the stomach brought out through an opening in the diaphragm, and an anastomosis made with the upper end of the esophagus. When this can be done the operation is not technically so difficult, nor should it carry a high mortality. This patient, however, died about the tenth day of a subphrenic abscess which had finally produced peritonitis.

At autopsy the mediastinum was entirely free of infection, and the union of the esophagus with the stomach patent without leakage.

Recently Dr. George Rhodes and I performed an operation in the same region on another patient. Here also the man was young and in good condition. We felt the case was operable, as his symptoms had not persisted for any great length of time. On exploration the mass was found surrounding the vena cava, and we were unable to complete the procedure.

In all of these cases it has been our custom to make a left rectus incision for the purpose of making a gastrostomy in those patients where the carcinoma was high up in the esophagus, or for a jejunostomy when the carcinoma was low down and anastomosis with the stomach seemed feasible.

A careful exploration is made at this time under the dome of the diaphragm for glandular metastasis. When these are present, operation is not done.

DR. FRANZ TOREK, Montclair, N. J.—I want to congratulate Dr. Adams most heartily on his success. The establishment of an anastomosis between the esophagus and the stomach after the removal of the carcinomatous portion is the crowning stage of the surgical attack on carcinoma of the esophagus. I am glad that Dr. Adams and Dr. Eggers confined their procedure of anastomosis to tumors low down in the esophagus because in those higher up it is rather difficult to bring enough of the stomach into the thorax to avoid tension on the suture connecting the two organs, and tension on the suture is the prime cause of failure to heal. Attempts to anastomose the stomach with the higher portion of the esophagus have been made, and Kirschner was successful in one case after transposing almost the entire stomach into the thoracic cavity; but that was not a carcinoma. In a subsequent attempt to repeat the method in a case of carcinoma, he failed. I believe it to be wise, at present, to limit these attempts to carcinoma in the lower part of the esophagus.

As to Dr. Eggers' paper in which he advocates dividing the operation for carcinoma of the esophagus into two stages, the first an approach through the neck, cutting the esophagus transversely and suturing the upper end to the skin of the neck, and the second, the thoracic part of the operation, it is true that the intrathoracic work would be shortened thereby. But the question is whether or not it is worth while. The time-consuming part of the operation is the separation of the carcinomatous esophagus from its connections and attachments, such as those with the arch of the aorta, and dividing some of the branches of the aorta, all of which has to be done intrathoracically. After the esophagus has been completely liberated, it does not take long to eviscerate it through an incision in the neck, and, furthermore, a much greater portion of the esophagus can be saved for antethoracic transplantation than is possible when the esophageal fistula is established by a separate primary opening through the neck. This latter drawback may perhaps be of no importance. Only by experience can we find out which is the preferable method.

DR. WILLIAM E. ADAMS, Chicago, Ill.—In answer to Dr. Churchill's question, we were rather surprised ourselves to find that the exposure through a lower thoracic incision was adequate for exploration of the upper abdomen. Exploration of the liver and the upper part of the stomach along the lesser curvature was just as easy as through an abdominal incision. We contemplated doing what Dr. Churchill suggested but decided that we would see how much exposure one could obtain by resection of the entire length of the eighth rib down to the costochondral junction; we found that on incising the diaphragm there was adequate exposure of the upper abdomen for exploration. This exposure also allowed for the performance of the operation with greater ease than doing a total gastrostomy through an abdominal approach.

I believe Dr. Overholt may have misunderstood me; we did not perform a gastrostomy before the operation. I heartily agree with both him and the other gentlemen who suggested doing a jejunostomy, if that is necessary, instead of a gastrostomy, because that will most surely hinder the necessary elevation of the stomach at the time the resection is performed.

The healing of the anastomosis, in our experimental animals, convinced us that the peritoneum is not necessary, at least not on both sides, for firm union of the anastomosis. In our dogs, where a cutting needle was not used in the operation as I described it, we did not have a single leak in the anastomosis performed in nine dogs. The peritoneum of the stomach may have played a role, naturally, in those results, because the operation was always a gastroesophagostomy.

I was very glad for Dr. Andrus' remarks. The time did not permit a review of the experimental work that has been done, and you all know it is voluminous; really his work and Dr. Miller's was very similar to ours, with the exception of minor details. I didn't know about his work when our experimental work was carried out, but other

than the technique of anastomosis our operation was very similar. As I recall, he removed the circular piece of the stomach wall and, as he said, made an aseptic type of anastomosis. During our procedure we made no attempt to keep the esophagus or stomach opening closed, as he did with a ligature, but prevented contamination and soiling as much as possible by packs about the field and by insertion of a small piece of gauze in the lumen of the esophagus.

Another point in connection with this, which I think is very important and which probably was the cause of the death of our first patient, is that work by the Japanese emphasized the danger of necrosis of the fundus of the stomach following ligation of the coronary artery along the lesser curvature. For this reason we resected the entire stomach and did an esophagojejunostomy. At the time of the operation it appeared unsatisfactory. The suture line was definitely on a tension, a factor which must be avoided to obtain successful results.

I also want to thank Dr. Brunn and Dr. Torek for their kind remarks.

THE RÔLE OF THE DUAL PULMONARY CIRCULATION IN VARIOUS PATHOLOGIC CONDITIONS OF THE LUNGS*

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EVEN though little is known concerning alterations in the bronchial arterial blood supply in various diseases, study of the bronchial arteries is not new, many sporadic, chiefly anatomic, attempts at study of the problem having been attempted in the past. Scattered papers have appeared in the literature for over a hundred years. A firm foundation for investigation in this field was established by the experimental work of Holman, Reichert, and Mathes upon dogs in 1930.[1]

Using a method with which a radiopaque substance, bismuth oxychloride, was injected into the bronchial arteries followed by stereoscopic x-ray films, we have studied the dual circulation in the lungs of seventy-four individuals dying of various diseases, and have discovered rather striking changes.

Until relatively recent years considerable controversy existed as to whether or not precapillary anastomoses existed between the bronchial and pulmonary arteries. Reisseisen[2] in 1822 and Zuckerkandl[3] in 1881 described arterial anastomoses. Guillot[4] as early as 1845, however, disagreed with the views of Reisseisen and claimed that the two arterial systems were independent. More recent workers such as Miller[5] in 1925, Holman and others[1] in 1930, and Berry[7] in 1935 demonstrated quite clearly that in normal lungs there exists an independence of the two systems, aside, of course, from capillary anastomoses. Berry arrived at his conclusion by injecting the bronchial artery of stillborn infants with a radiopaque substance, barium sulfate, and taking x-ray pictures afterwards. Perfusion studies by Berry and Daly[8] in 1931 demonstrated capillary anastomoses from the bronchial arteries not only with the pulmonary arteries but with the pulmonary veins. The latter are the more important, returning approximately three times more blood to the systemic than the former returns to the pulmonary arterial circulation. Ghoreyeb and Karsner[9] in 1913 attempted to study the rôle of the bronchial and pulmonary arterial circulations by injection studies, and also arrived at the conclusion that the two systems were independent except for capillary anastomoses.

A few notes have also appeared sporadically in the literature referable to changes in one system occurring simultaneous with, or subsequent to,

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alterations in the other. Virchow[10] as early as 1847 and 1851 demonstrated that changes in the pulmonary arterial system would influence the bronchial arteries. He demonstrated that chronic obstruction of a pulmonary arterial branch to one lung lobe would cause an increased bronchial arterial development. This observation was unheeded until the experimental work of Holman et al.[1] on dogs with sterile and infected emboli which produced the same changes. Sixty-five years following Virchow's observation, however, Christeller[11] demonstrated the development of a collateral circulation through the bronchial arteries in 21 cases of pulmonary atresia and stenosis. For further details referable to the historical aspects, the reader should refer to the article by Berry, Brailsford, and Daly[12] appearing in 1931.

ANATOMY

The bronchial arteries vary in number and sites of origin. In the majority of cases, however, they arise from the anterior surface of the aorta at the level of the fourth thoracic vertebra. On the left there are customarily two arteries, and on the right, one. Occasionally, one may have an anomalous origin from the third intercostal artery. In a few cases tiny anterior bronchial arteries are present and arise from the internal mammary arteries. The amount of blood supplied to the lungs by the bronchial arteries in the normal individual is relatively small. Fine ramifications extend only as far as the terminal bronchioles (ductus alveolaris) where they break into a capillary network, as shown by Miller.[5] Most of the blood from the bronchial arteries is returned by the pulmonary vein, although small amounts are returned by the pulmonary artery, and the bronchial veins, the latter being branches of the azygos. The communications between the bronchial artery and the branches of the pulmonary arteries are capillary in size. In none of our normal lungs were we ever successful in demonstrating them by injection of radiopaque substance.

PHYSIOLOGY

The blood pressure in the pulmonary artery is variously estimated at approximately 40 mm. of mercury. Exact determinations in the bronchial arteries are, of course, not available. It is to be remembered that the aortic pressure is at least 120 mm. of mercury, and that the bronchial arteries have their sites of origin relatively high in the aorta, and that these arteries are quite short as well as straight.

METHOD

For the demonstration of graphic anatomic changes, considerable difficulty has been encountered because of the lack of a suitable injection material. We have found that of the radiopaque substances available, bismuth oxychloride is the best and is preferable to barium sulfate,

the former giving a smoother mixture, the thickness of which can be better regulated and controlled, so that only the arterial and not the capillary system can be injected. Our studies were carried out by injections of the vessels of the lung with Hill's mass,[13] a suspension of 20 per cent bismuth oxychloride in 11 per cent acacia, with water as a medium. In order to obtain satisfactory injection of the bronchial artery, it is necessary to remove the lungs in toto with the aorta. Great care must be exercised in removing the lungs in order to safeguard tearing of the pleura. In our experiments the heart was removed, cutting the aorta and pulmonary artery just above their valves. The arch of the aorta was removed with the lungs along with generous stumps of the

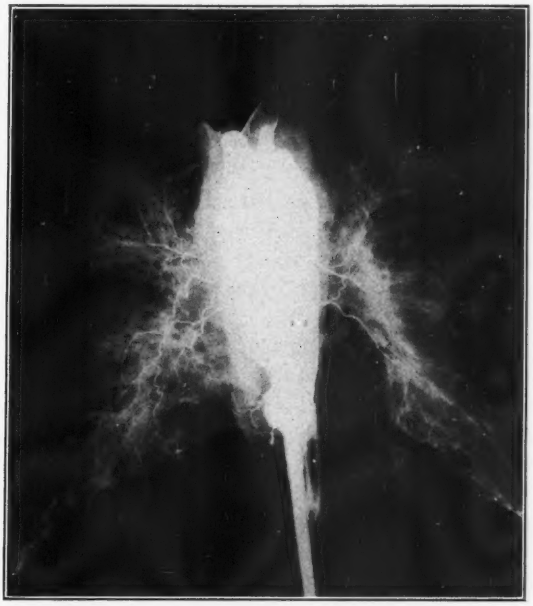

Fig. 1.—Normal bronchial artery injection.

neck vessels, which were tied off. The intercostal arteries were cut on each side along the vertebrae, and a segment of each removed with the aorta. The aorta was cut just above the diaphragm. All stumps of vessels were then ligated. A cannula was tied tightly into the proximal end of the aorta. Cannulas were tied into the pulmonary artery, and into the trachea. The lungs were then inflated with air through the tracheal cannula to a degree as near as possible to their normal. The bronchial arteries were injected through the thoracic aorta with the mixture mentioned above. This mixture had been previously finely ground for at least twenty-four hours in a ball mill. The bismuth mixture was injected into the aorta under a pressure of 120 mm. of mercury. Immedi-

ately following the injection, stereoscopic x-ray films were taken. After satisfactory injection, and x-ray films of the bronchial arteries had been obtained, the pulmonary arteries were injected. The pulmonary arteries were injected with a pressure of approximately 60 mm. of mercury, and stereoscopic x-ray films taken immediately afterward. The vessels were then tied off with the opaque material remaining in them. Formalin or a Kaiserling solution was injected into the trachea to aid in fixation, and still inflated, the lungs were suspended in a solution of formalin or a Kaiserling solution. This makes it more possible to preserve relationships following fixation. After thorough fixation, the lungs were sectioned and microscopic sections taken (Fig. 1).

CASE 1.—Normal. XXXVIII-43. A 64-year-old male, who died of an acute generalized peritonitis. Injections showed normal bronchial arteries.

PATHOLOGIC RELATIONS BETWEEN THE BRONCHIAL AND PULMONARY ARTERIAL SYSTEMS

We found that not only did alterations in the bronchial arterial circulation occur in various diseases, but that generally uniform changes of a given order occurred characteristically in various diseases. We injected the circulation in the lungs from 74 human cases, included in which were cases of tuberculosis, silicosis, cardiac disease, malignancies, emphysema, asthma, congenital cystic disease, chronic inflammatory processes, infarction, and normals. The only groups of cases sufficiently large to justify any conclusions were tuberculosis, cardiac disease, and malignancies.

(a) *Pathologic Relations Due to Hypertrophic Processes in the Pulmonary Parenchyma.*—In neoplastic disease of the lung it was uniformly noted that primary malignancies were constantly associated with a marked increase in the supply of bronchial arterial blood to the region involved. In metastatic malignancies no such change occurred. The explanation for this is not known, although a number of factors may play a rôle. First, a concomitant chronic inflammatory process; and, secondly, accompanying occlusion of the branches of the pulmonary artery to the given lobe or site of origin of the neoplasm. Chronic empyemas in humans, pneumonias in dogs, experimental occlusion of the pulmonary artery in dogs, and occlusion of the pulmonary artery subsequent to infarction are all accompanied by dilatation of the bronchial artery. Upon the basis of this evidence, it is likely that bleeding in cases of pulmonary neoplasm is indicative of a primary and not a metastatic tumor. In passing it is of interest to notice the possible relationship between the status of the capillary network of the bronchial artery and the distribution of metastases in carcinoma of the lung. The fact that the bronchial artery empties three times more blood into the pulmonary vein than into the pulmonary artery might offer an explana-

tion as to why systemic metastases are the rule in cases of carcinoma of the bronchus. This tendency would be enhanced by the marked increase in bronchial artery blood supply in such cases. In the Stanford series of one thousand cases of carcinoma, metastases from carcinoma of the lung to other parts of the lung parenchyma are only about one-half as frequent as from carcinomas arising in the visceral organs and thyroid. In metastatic pulmonary disease the inflammatory component is absent, and the cases which we have injected indicate that the surrounding pulmonary parenchyma and circulation is merely displaced.

CASE 2.—Carcinoma of bronchus (squamous-cell type, right lower lobe bronchus). XXXIX-435, A. D., fifty-five years old. Duration of symptoms unknown exactly, probably several weeks. At autopsy the heart was normal in weight and size. The

Fig. 2.—Carcinoma of bronchus (right lower lobe). XXXIX-435. Branches of bronchial artery to right lower lobe are greatly dilated, tortuous, and more numerous. Left bronchial arteries normal.

lungs showed old, puckered scars at the apices. On the right many firm, fibrous adhesions were present between the visceral and parietal pleura over the lower lobe, and showed a marked semigelatinous edema of the adhesions. On section the lower lobe was contracted, firm, and composed of very hard but friable tumor tissue, arising from and surrounding the bronchus. The center of the mass was necrotic, forming a cavity lined by tumor, measuring 3.0 cm. in diameter, and filled with blood. Metastases were present in the peribronchial and peritracheal lymph nodes as well as in the kidneys.

Injection of the bronchial arteries showed that the vessel supplying the right lower lobe was greatly dilated, tortuous, and had given rise to a rich vascular bed surrounding and involving the tumor (Fig. 2).

CASE 3.—Metastatic sarcoma to both lungs (primary in uterus). XXXIX-244, B. G., aged seventy (?) years. Duration of symptoms unknown. At autopsy the

heart was normal. The lungs contained bilateral, solitary masses in each upper lobe, measuring up to 3.0 cm. in diameter.

Injection of the bronchial artery showed normal vessels (Fig. 3).

(b) *Pathologic Relations Due to Obstructive Lesions, Pulmonary and Cardiac, Sclerotic, Congestive, etc.*—In this series the cases of old rheumatic heart disease were the most interesting. These cases showed characteristic changes in the bronchial and pulmonary arteries as noted in the x-ray films of the injected lungs. Not only were the bronchial arteries slightly to moderately dilated, but there also occurred a constant widening of the capillary anastomoses between the bronchial arteries and the branches of the pulmonary arteries, so that the bismuth oxychloride mixture poured into branches of the pulmonary arteries.

Fig. 3.—Metastatic sarcoma to both lungs (primary in uterus). XXXIX-244. The bronchial arteries are normal and unaltered.

This finding was constant in cases of hypertrophy of the right ventricle and failure of the right heart. Similar anastomoses occurred in cases of syphilitic heart disease, hypertension, and generalized arteriosclerosis, but were less constant and usually of milder degree than in cases of rheumatic heart disease. In all such cases there was clinical evidence indicative of an increased pulmonary venous pressure.

We believe that the widening of the capillary anastomoses may be due to two factors—one, an increase in pulmonary venous pressure, following or accompanying failure or decompensation of the left ventricle and auricle; and secondly, disease of the bronchial and pulmonary arteries, especially in cases of old rheumatic fever. With an increase in pulmo-

nary venous pressure, anastomoses would then develop at the site of the diseased blood vessels in the pulmonary parenchyma. Inasmuch as normally three times more blood is returned by the way of capillaries from the bronchial arteries to the pulmonary vein than to the pulmonary artery, we feel that an increase in pulmonary venous pressure would act as a block, and thereby predispose for widening of the capillaries between the bronchial arteries and the pulmonary arteries with their lowered blood pressure. The graphic picture produced in the stereoscopic x-ray films is so typical that the experienced investigator can identify with astonishing accuracy the cases of rheumatic heart disease.

CASE 4.—Rheumatic heart disease with mitral stenosis. XXXIX-425, S. O., aged fifty-four years. Duration of cardiac symptoms eight years. History of rheumatic

Fig. 4.—Rheumatic heart disease with mitral stenosis. XXXIX-425. Bronchial arteries are dilated and tortuous. Numerous anastomoses between the bronchial and pulmonary arteries.

fever in 1917. At autopsy the heart weighed 530 gm. The left ventricle measured 10 mm. in thickness, and the right, 5 to 6 mm. A typical mitral stenosis was present.

Injection studies showed a slight to moderate increase in the branching and tortuosity of the bronchial arteries, as well as the partial filling of numerous branches of the pulmonary artery from very large anastomoses. These were easily seen stereoscopically and proved by dissection (Fig. 4).

CASE 5.—Rheumatic heart disease with aortic stenosis. XXXIX-427, P. S., aged seventy-three years. Duration of symptoms indefinite, at least two months. At autopsy the heart weighed 460 gm. The left ventricle measured 12 mm., and the right, 4 mm. in thickness. The aortic valve leaflets were markedly thickened and calcified, and the leaflets adherent. Recent soft vegetations at the margins. Small fibrous scar at the apex of the left ventricle.

Injection of the bronchial arteries showed them to be moderately dilated and tortuous, with a moderate increase in fine branching. There were also a number of anastomoses between the bronchial arteries and the pulmonary arteries, particularly on the right (Fig. 5).

White and Brenner[14] have recently drawn attention to rather extensive vascular changes which can be demonstrated histologically in various diseases. At the present time we have not correlated the histologic changes noted in our cases.

Coronary Sclerosis.—Four cases of coronary sclerosis with fatal thrombosis were injected, and in none of these was any alteration noted in the bronchial artery circulation. The rather small anterior bronchial arteries were not injected in these cases, and accordingly no opportunity

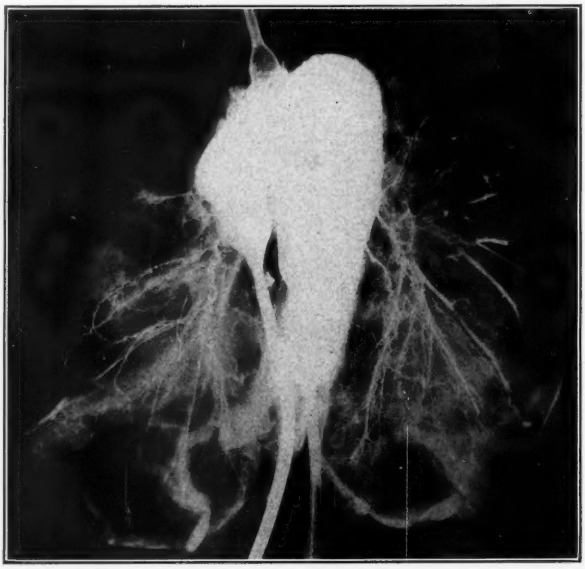

Fig. 5.—Rheumatic heart disease with aortic stenosis. XXXIX-427. Bronchial arteries slightly to moderately dilated, longer than normal, and in places communicating by anastomoses with the pulmonary arteries.

was available to note whether or not changes occurred in these vessels, such as might be expected in the light of Wearn's work,[15] demonstrating the anterior bronchial arteries as a source of extracardiac anastomoses with the coronary arteries.

Ayerza's Disease.—In our series was one case which clinically was called Ayerza's disease. At autopsy the man had an extensive sclerosis of the pulmonary arteries, and a marked hypertrophy of the right ventricle. Injection of the bronchial arteries culminated in an injection of the pulmonary arterial system.

CASE 6.—Ayerza's disease. XXXVIII-001, E. B., aged (?). Duration of symptoms and clinical story: Worked in a smelter in 1925 for ten months, and since then

has had cough and dyspnea. In the last fourteen months before entry he had pain in the chest and lost considerable weight. Red blood count 5,200,000. Hemoglobin 108 per cent Sahli.

At autopsy the heart weighed 400 gm., and the right ventricle was markedly thickened. The lungs were covered with numerous fibrous adhesions and showed many large emphysematous bullae. The pulmonary arteries contained a number of elevated, yellowish plaques in the intima.

Injection of the bronchial arteries showed that the larger radicals of the pulmonary artery were all filled with the bismuth mixture (Fig. 6).

Again, the most striking changes were in the cases of rheumatic heart disease, dying of failure of the right heart. Our injection studies indicate that it is likely that the onset of right ventricular hypertrophy

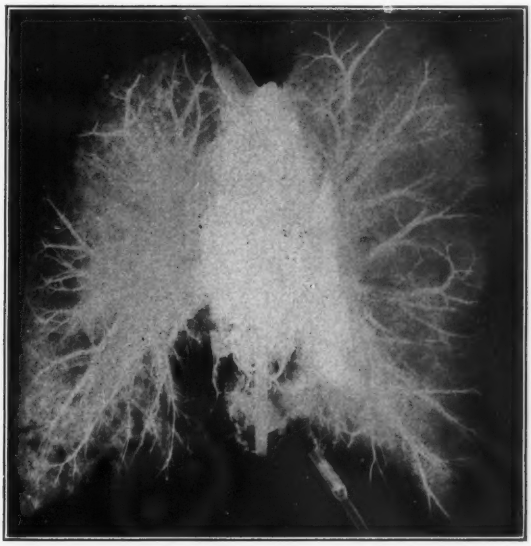

Fig. 6.—Ayerza's disease. XXXIX-0.001. Injection of the bronchial arteries resulted in a filling of the pulmonary tree.

and failure is hastened by the widening of the capillary anastomoses to the pulmonary arteries, opening up direct channels between a high pressure and a low pressure circulation. This change is probably accentuated with an increase in pulmonary venous pressure.

(c) *Pathologic Relations Due to Inflammatory Lesions, Chronic and Acute: Pulmonary, Cardiac, and Mixed.*—The cases in this series should be considered in two groups, tuberculous and nontuberculous. In every case of tuberculosis consistent changes occurred in the bronchial arteries. The more chronic and extensive the tuberculosis, the more marked was the dilatation, tortuosity, and the more numerous the ramifications of these vessels. In arrested cases of tuberculosis residual changes were present.

The injection studies indicate quite clearly that an increase in the supply of oxygenated blood occurs in and about the diseased areas. In some cases this increase must have been enormous. This is closely comparable with observations made by Holman et al.[1] in experimental tuberculosis in dogs. Possibly the pulmonary arterial vessels being more numerous in the parenchyma of the lung and more thin-walled are more rapidly obliterated. The dilatation of the bronchial arteries occurs in part, at least, as a result of obliteration of pulmonary arterial bed in the diseased areas. When the process is associated with, or complicated by, silicosis with hypertrophy of the right heart, anastomotic channels between the bronchial and pulmonary arteries appear. Miller[5] has shown

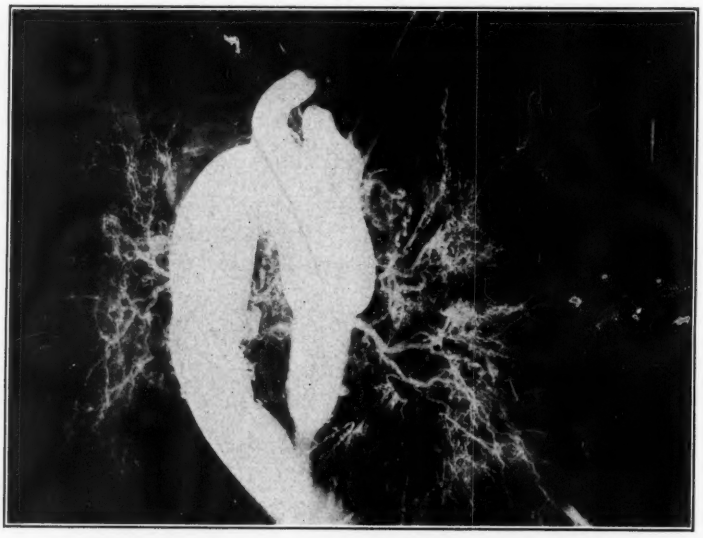

Fig. 7.—Chronic pulmonary tuberculosis, far advanced. XXXIX-580. Injection of the bronchial arteries showed a moderate to marked dilatation of the bronchial arteries on both sides with the development of numerous small branches.

that the bronchial artery terminates in the capillary plexus about the ductus alveolaris. Workers in South Africa and others have demonstrated that the initial site of origin for the silicotic tubercle is in the lymphoid tissue at the ductus alveolaris. Possibly disease at the site of the capillary bed predisposes for widening of capillary communications between the bronchial and pulmonary arteries.

Some of our cases demonstrated quite clearly that bleeding is occasionally of bronchial artery origin. In some cases anastomotic channels develop through adhesions between lobes, and may be responsible for sustained hemorrhage following ligation of a branch of the pulmonary artery to a lobe for prevention or arrest of hemoptysis.

CASE 7.—Chronic pulmonary tuberculosis, far advanced. XXXIX-580, S. B., aged forty-five (?) years. Duration of symptoms two years. At autopsy large cavities in both upper lobes. Bronchiogenic distribution of tubercles scattered throughout lower lobes.

Injection of the bronchial arteries shows a moderate to marked dilatation of the bronchial arteries on both sides with the development of numerous small branches (Fig. 7).

CASE 8.—Subacute pulmonary tuberculosis, far advanced. XXXIX-389, V. W., aged thirty-three years. Duration of symptoms three and a half months. Exposure for four years.

At autopsy the pleura of each lung showed a marked thickening. In the left lung the upper lobe was subtotally replaced by large areas of caseous pneumonia, and

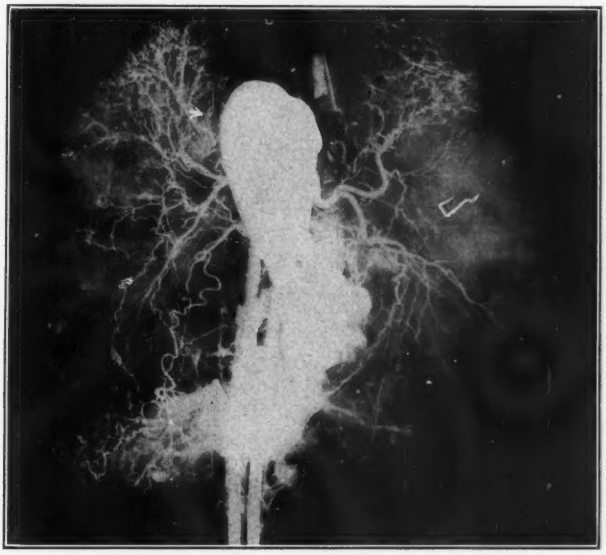

Fig. 8.—Subacute pulmonary tuberculosis, far advanced. XXXIX-389. Injections of the bronchial arteries showed extensive changes, the vessels being tremendously enlarged, tortuous, and associated with many new branches.

conglomerate tubercles, some of which were older and more fibrous. Several small cavities were present at the apex. The lower lobe was well aerated, but contained many scattered tubercles.

The right lung contained several large cavities in the upper and middle lobes filled with thick, foul, purulent material. Surrounding the cavities were numerous tubercles and areas of caseous pneumonia. Scattered tubercles were present in the lower lobe.

Injections showed extensive changes in the bronchial arteries which were tremendously enlarged, tortuous, and possessed many new ramifications (Fig. 8).

CASE 9.—Chronic pulmonary tuberculosis. XXXVIII-128, T. McK., aged sixty-four years. Duration of symptoms twenty-two years. At autopsy the heart was normal. The lungs showed large anthracotic scars in both upper lobes. On cut

section several small fibrocaseous areas from 0.5 to 1.5 cm. in diameter were scattered throughout the upper lobes. Small tubercles were scattered throughout the remainder of the lungs. The lower lobes were slightly emphysematous. The peribronchial lymph nodes were large, anthracotic, and contained a few small fibrocaseous areas. In addition to the pulmonary findings, tuberculosis of the intestines, liver, spleen, and seminal vesicles was also found.

Injection of the bronchial arteries showed a marked dilatation and a moderate tortuosity of the larger branches and the development of numerous small branches in both upper lobes (Fig. 9).

CASE 10.—Chronic pulmonary tuberculosis with acute exacerbation and dissemination. XXXIX-385, T. L., aged thirty-eight years. Duration of symptoms four years.

Fig. 9.—Chronic pulmonary tuberculosis. XXXVIII-128. Figure shows upper left lobe dilated, tortuous bronchial arteries, and many new, small arteries.

Four years prior to death he developed a right-sided pleurisy following which an x-ray diagnosis of pulmonary tuberculosis was made. Two years later he developed a genitourinary tuberculosis.

At autopsy the heart was small, weighing 250 gm. The left lung showed a marked pleural thickening. Numerous small cavities were present at the apex, measuring from 2 to 15 mm. in diameter. Many conglomerate caseous areas of varying size were scattered throughout both lobes. The right lung also showed a marked pleural thickening and numerous cavities in the upper lobe, measuring from 2 to 3 cm. in diameter. The remainder of the upper lobe was almost completely replaced by large areas of caseous pneumonia. The middle lobe contained many small tubercles. Scattered in the lower lobe, at the extreme base of which was a network

of thin-walled cavities 0.5 to 1.5 cm. in diameter, containing yellow foul purulent material. The peribronchial lymph nodes were large and contained numerous small yellow caseous tubercles. Other tuberculous lesions were found in the kidneys, ureters, prostate, bladder, adrenal, liver, and spleen.

Injection of the bronchial arteries showed a moderate increase in tortuosity and branching of the bronchial arteries. At the right apex branches of the bronchial arteries freely communicate with two cavities. This indicates very clearly that bleeding suffered before death in this case was of bronchial artery origin (Fig. 10).

CASE 11.—Subacute pulmonary tuberculosis. XXXVIII-84, A. K., negro, aged fifty-two years. Duration of symptoms indefinite, possibly fourteen months. Unsuc-

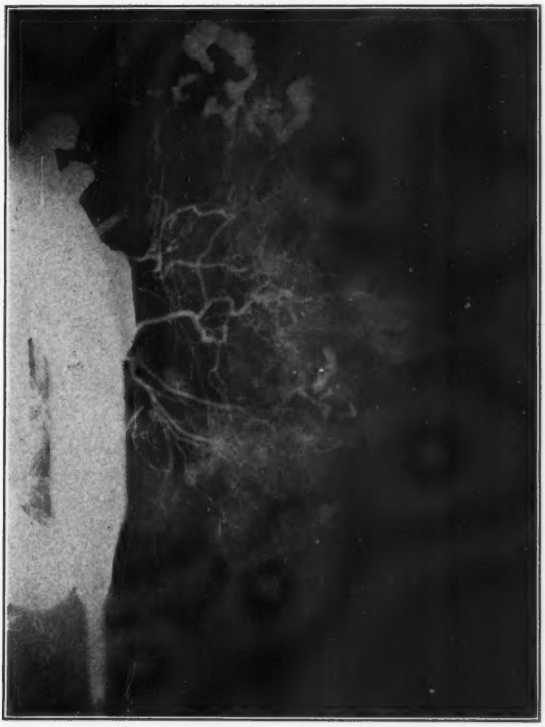

Fig. 10.—Chronic pulmonary tuberculosis with acute exacerbation and dissemination. Bleeding into apical cavities. XXXIX-385. Right upper lobe. Injection of the bronchial arteries shows dilated tortuous bronchial arteries with free escape of the injection mixture into the apical cavities.

cessful attempt to collapse right lung. Eight days prior to death was taken to surgery where a fish-line suture was passed around the hilus of the upper lobe in an attempt to arrest a continuous, oozing hemoptysis.

At autopsy dense fibrous adhesions were present between the parietal and visceral pleurae. The interlobar fissures were obliterated. The right upper lobe contained large, smooth-walled intercommunicating cavities lined by caseous material and crossed by thin fibrous bands. Many of these bands contained vessels filled with the injection mixture. The lower and middle lobes showed extensive fibrosis, and large numbers of moderate sized caseous tubercles, some of which were confluent.

Practically no aerated lung was present. The left lung showed a scar at the apex, and many scattered small caseous tubercles throughout.

Injection of the pulmonary artery with a barium sulfate mixture showed that it had filled the pulmonary artery in the upper lobe distal to the site of ligature by having passed through vessels which had developed in the interlobar adhesions and formed anastomoses between the vessels of the middle and upper lobes.

As a result of a chronic interlobar pleurisy, anastomoses had developed between the pulmonary arterial branches of the upper and middle lobes into branches of the pulmonary artery of the upper lobe distal to the point of ligature (Fig. 11).

CASE 12.—Silicosis (mixed, infective type). XXXIX-416, J. M., Italian quartz miner, aged forty-six years. Duration of symptoms: Had no complaint of cough, sputum, or shortness of breath. Tuberculous lymph node removed from neck five years before present entry. Complaint on entry was joint pain for five months.

Fig. 11.—Subacute pulmonary tuberculosis. XXXVIII-84. Slow, progressive hemoptysis with surgical attempt to arrest it by passing ligature around hilus of upper lobe. Injection of pulmonary arterial tree shows a filling of the branches of the pulmonary artery of the upper lobe on the right, distal to point of ligature, the vessels being filled by anastomoses which had developed through dense interlobar adhesions from the middle lobe.

At autopsy the heart was normal. The pleura of both lungs was thickened and covered with fibrous adhesions. On cut-section both lungs were seen to contain numerous small diffusely scattered fibrocaseous nodules, ranging from 1 to 5 mm. in width. Tuberculous lesions were also present in the joints, intestines, liver, kidneys, seminal vesicles, epididymis, and spleen.

Injections of the bronchial arteries showed a marked dilatation, tortuosity, and increase in the fine branching of the bronchial arteries on both sides. Also, a number of anastomoses with the pulmonary arteries were present (Fig. 12).

Nontuberculous Inflammatory Conditions.—In the nontuberculous group of cases which included bronchiectasis, lung abscess with bronchial

fistula, polyserositis, chronic empyema, and chronic lung abscess, alterations in the bronchial artery were uniformly noted. These consisted in a dilatation of the smaller branches in the diseased areas, and were associated with the establishment of many new vessels. One case of bronchiectasis in a young female adult showed a myriad of new bronchial arteries along the course of the bronchi in the diseased lobe. A case of chronic empyema showed not only dilated bronchial arteries, but an extension of the dilated vessels much further to the periphery of the lung than normal, and the establishment of anastomoses between the bronchial and pulmonary arteries on the opposite side, where small patches of partially carnified bronchopneumonia were found.

Extension of the bronchial arteries to the periphery of the lung was also well illustrated in a case of polyserositis with greatly thickened

Fig. 12.—Silicosis (mixed, infective type). XXXIX-416. Injection of the bronchial arteries shows not only dilated, tortuous bronchial arteries, but also the development of anastomoses between the small branches of the bronchial arteries and branches of the pulmonary artery.

pleura where extension of dilated, tortuous vessels to the pleura was striking. On the opposite side bronchial-pulmonary anastomoses were also present.

CASE 13.—Bronchiectasis (7/27/36). Injection of the bronchial arteries showed an extensive network of new bronchial artery branches in the diseased lower lobe. The main bronchial artery to this lobe was also slightly dilated and quite tortuous (Fig. 13).

CASE 14.—Chronic empyema. XXXIX-290, W. T., aged seventy-four years. Duration of symptoms one month. At autopsy the heart was normal in size. The left lung showed a very extensive fibrous thickening of the pleura, ranging from 1 to 6 mm. in thickness with a pocket containing approximately 100 c.c. of thick yellow pus.

Both lungs were congested with scattered areas of consolidation. The pleura of the right lung showed a slight fibrous thickening, and a few small calcified pleural nodules.

Injection of the bronchial arteries: On the left there was a moderate increase in fine branching and tortuosity of the bronchial arteries. There was a marked increase in fine branching of the right bronchial arteries, and extensive anastomoses with the pulmonary arteries (Fig. 14).

CASE 15.—Polyserositis, chronic (Pick's disease). XXXIX-249, S. L., aged thirty-nine years. Duration of symptoms eight years.

At autopsy the heart was about normal in size. The pericardium was very thick and fibrous throughout, particularly over the left ventricle. The pericardial cavity was obliterated by dense fibrous adhesions.

Fig. 13.—Bronchiectasis (7/27/36). The bronchial arteries to the right lower lobe are tremendously increased in number forming a fine network about the diseased bronchi and bronchioles.

The left pleural cavity contained 700 c.c. of clear fluid, and the right 200 c.c. The lungs were subcrepitant, and the parietal and visceral pleura showed an old fibrous thickening with extensive thick "fiddle-string" like adhesions throughout. The lower lobes were contracted and rounded.

Injection of the bronchial arteries showed on the right a marked tortuosity of the bronchial arteries, two large tortuous branches, extending out into the periphery of the lower lobe. On the left there was slight increase in the bronchial artery bed, and several anastomoses with the pulmonary artery (Fig. 15).

Injection of the lungs showing bronchopneumonia showed a slight to moderate dilatation of the bronchial arteries, and a marked collapse of the pulmonary arteries in the areas of involvement. Possibly collapse of the pulmonary vessels is conducive to dilatation of the bronchial

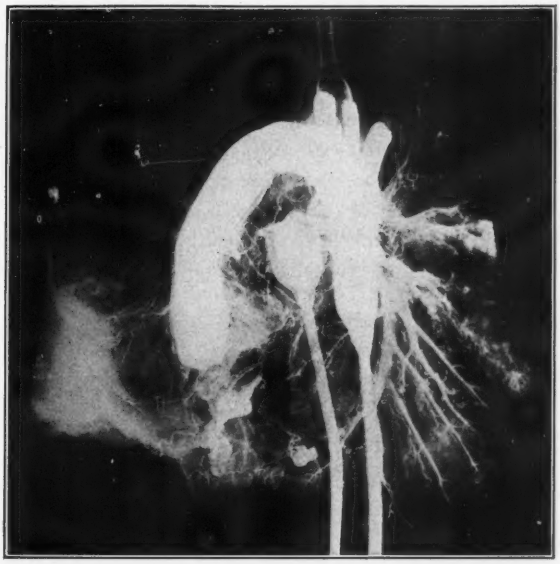

Fig. 14.—Chronic empyema. XXXIX-290. Bronchial artery injection showed on the left a moderate increase in the fine branching and tortuosity of the bronchial arteries, and the development of numerous anastomoses with the pulmonary arteries.

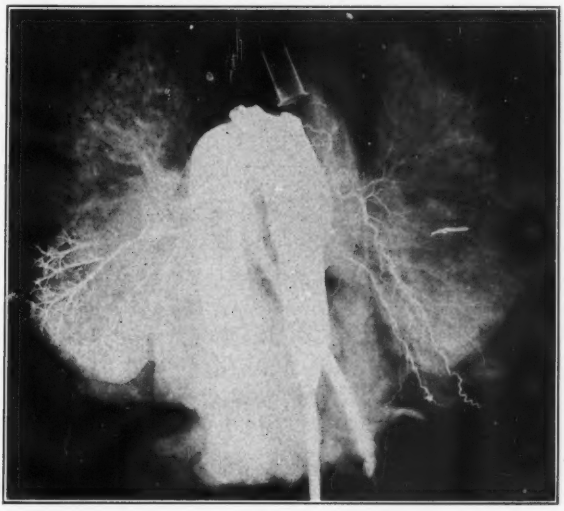

Fig. 15.—Polyserositis, chronic (Pick's disease). XXXIX-249. Injection of the bronchial arteries showed on the right a marked tortuosity of the bronchial arteries, two large tortuous branches extending out into the periphery of the lower lobe. On the left, a slight increase in the bronchial artery bed, and several anastomoses with the pulmonary artery.

arteries. Experimental evidence from dogs, and the observations of Christeller[11] and Virchow[10] are in agreement with our observations.

(d) *Pathologic Relations Due to Processes of Debatable Etiology—Emphysema and Asthma.*—Unfortunately, only two cases of asthma and two of emphysema were present in our series. The degree of emphysema in each of our cases was not especially marked. In these two cases of emphysema, however, the finer branches of the bronchial arteries seemed to be more numerous and to extend for a slightly longer distance into the parenchyma of the lung than normally seen. One of our cases showed the development of occasional anastomoses between the bronchial

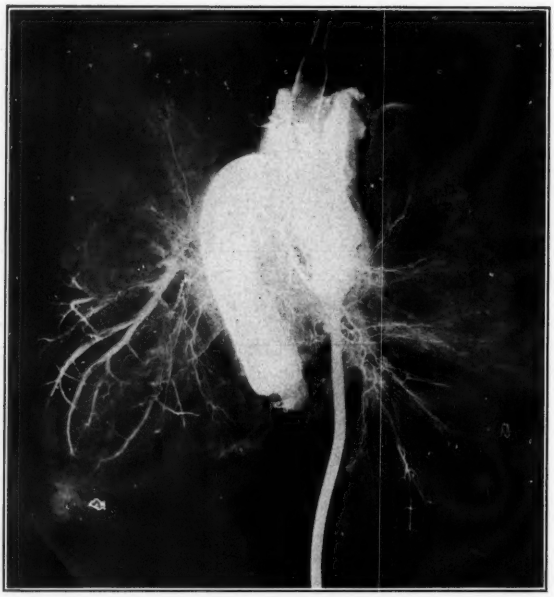

Fig. 16.—Emphysema and marked arteriosclerosis with cardiac hypertrophy and dilatation. XXXIX-440. Injection of the bronchial arteries showed a slight increase in fine branching of the arteries. Numerous anastomoses with the pulmonary arteries were present, particularly in the left lower lobe.

and pulmonary arteries. We do not feel justified in drawing conclusions from these two cases, even though a slight hypertrophy of the right ventricle was present.

CASE 16.—Emphysema and marked arteriosclerosis with cardiac hypertrophy and dilatation. XXXIX-440, P. V., aged sixty years. Duration of symptoms of cardiac failure indefinite, but at least two months.

At autopsy the heart weighed 520 gm. The left ventricle measured 12 mm. in thickness and the right 4 to 5 mm. No valvular disease. Both lungs were large, crepitant, reddish brown in color, and showed large emphysematous bullae at the apices and along the anterior margins.

Injection of the bronchial arteries showed a slight increase in fine branching of the bronchial arteries. Numerous anastomoses with the pulmonary arteries were present, particularly in the left lower lobe (Fig. 16).

In the two cases of asthma the dilatation of the finer branches of the bronchial arteries was especially marked. No evident alteration, however, was noted in the major trunk branches.

CASE 17.—Asthma. XXXIX-511, D (Fig. 17).

(e) *Pathologic Relations Due to Congenital Anomalies.*—The compensatory dilatation of the bronchial artery accompanying pulmonary stenosis or atresia has already been noted.[11] In our series we had two

Fig. 17.—Asthma. Bronchial artery injection showed that the major branches were about normal in size, but that there was a moderate dilatation of the smaller branches which also appeared to be more numerous than normal.

cases of congenital cystic disease of the lungs. One was of unusual interest, occurring in a male of thirty years, who died with a marked hypertrophy of the right ventricle for which no anatomic cause could be found. Upon injecting the bronchial arteries the pulmonary arterial tree filled readily, as proved by dissection. In the stereoscopic films, the bronchial arteries were observed to be large, dilated, and rather tortuous. We believe that it is highly possible that the numerous and extensive bronchial pulmonary arterial anastomoses were responsible for the hypertrophy and failure of the right ventricle, inasmuch as direct openings were present between a high pressure (systemic) circulation and a low pressure (pulmonary) circulation, producing a condition not

different from that which exists in arteriovenous fistula, or patent ductus arteriosus. In the other case bronchial artery injection studies showed a slight to moderate dilatation of the bronchial arteries and a few bronchial pulmonary arterial anastomoses. Injection of the pulmonary arterial tree showed nicely the displacement of the pulmonary arteries around the cysts. These vessels seemed to end in a fine network of vessels about the cysts.

CASE 18.—F. Q., 7c156, aged thirty (?) years. Congenital cystic disease of lungs. Right-sided heart failure.

At autopsy numerous thin-walled cysts in both lungs. Heart moderately enlarged and slightly dilated. The right ventricle was considerably hypertrophied and measured 5 mm. in thickness.

Fig. 18.—Congenital cystic disease of lung with hypertrophy and failure of the right heart. 7C156. Injection of the bronchial arteries shows dilated, tortuous vessels, some of which are indicated by arrows. Due to numerous anastomoses between the bronchial and pulmonary arteries, the latter filled completely as a result of the bronchial artery injection.

Injection of the bronchial arteries showed dilated tortuous arteries from which the injection mixture ran freely into the pulmonary arteries, completely filling them (Fig. 18).

DISCUSSION

Injection of the bronchial arterial system by a radiopaque substance (bismuth oxychloride, acacia suspension), which fills only the arteries and not the capillaries, has demonstrated rather striking and uniform changes in various diseases. It has opened and given impetus for further study of many problems in the fields of not only physiology and clinical medicine, but also of pathology and thoracic surgery. In our study we

made no attempt to maintain pressure in the pulmonary arteries at approximate normal pressures during injection of the bronchial arteries. On account of the viscosity of the injection medium, however, none of the material extended beyond vessels smaller than 12 to 15 micra in diameter. This was constant in our control cases. We believe that the changes noted with the uniform patterns produced are significant, and cannot possibly be explained on the basis of artefact and chance.

The results from this phase of the problem warrant a more careful approach to the histologic study of the lungs and their vessels than is done at the present time.

Primary malignancies of the lungs are uniformly accompanied by the development of a rich bronchial artery supply. It is quite evident that any bleeding which occurs is probably bronchial artery in origin.

In cases of rheumatic fever with valvular disease we must consider not only the mechanical effects resulting from increased pulmonary venous pressure, but also the rôle of bronchial pulmonary arterial anastomoses elicited by disease of the vascular structures within the lungs. Anatomic changes in these vessels would either augment or decrease the progressive changes which would ensue gradually due to pressure phenomena alone.

In tuberculosis an increase in the supply of bronchial arterial blood occurs to the parts involved. Infection and occlusion of the pulmonary arterial branches probably contribute to this change. The appearance of bronchial pulmonary anastomoses in cases of silicosis is of utmost interest. Possibly they might explain why nonsilicotic tuberculous cases rarely die of right-sided heart failure, whereas, patients with silicosis frequently do.

In cases of congenital cystic disease of the lungs where large amounts of pulmonary parenchyma are replaced by cysts, the bronchial arteries are apt to be dilated. In all obscure cases of hypertrophy and failure of the right heart, the possibility of communications between the bronchial and pulmonary arteries must be kept in mind.

In this paper we offer no final explanations as to the mechanisms productive of these changes. We do wish to call to your attention, however, the method used in this study as another approach or adjunct in the study of pulmonary disease. Attempts should be made to study the physiologic aspects by means of the Anrep heart-esophagus-lung preparations.

In determining the sites of bleeding in cases of tuberculosis and malignancies, the method is invaluable to the pathologist. The studies indicate that bleeding in tuberculosis and neoplastic disease is more apt to be bronchial in origin, and is apt to persist on account of the dilated, tortuous vessels produced.

SUMMARY

1. A method is described for the injection of bronchial and pulmonary arteries in human lungs by the use of bismuth oxychloride acacia suspension which is radiopaque.

2. The bronchial arteries established a rich vascular bed surrounding and involving primary lung tumors, in contradistinction to metastatic tumors, where they remain uninvolved.

3. In cardiovascular diseases which result in heightened pulmonary venous pressure, and possibly associated with lesions of the pulmonary vascular tree, numerous bronchial-pulmonary arterial anastomoses develop.

4. The bronchial arteries show marked changes in subacute and chronic tuberculosis. The arteries become dilated, tortuous, and establish new ramifications.

5. In all cases of obscure hypertrophy and failure of the right heart, one should rule out the possibility of widened communications between the bronchial and pulmonary arteries.

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OBSERVATIONS ON SOURCES OF PULMONARY HEMORRHAGE AND ATTEMPTS AT ITS CONTROL*

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HEMORRHAGE is a serious complication of pulmonary tuberculosis. Schroeder estimates that 25 to 30 per cent of all tuberculous patients bleed at some time in the course of their disease. Comparatively seldom, however, do they bleed to death. Sweeney of Chicago finds that exsanguination figures as a cause of death in about thirty per thousand of all autopsies for this disease. Considerable hemorrhage causes aspiration of infected blood into distal parts of the lung, contributes to spread disease, and often foreruns rapid progression and decline. There is reason, therefore, for endeavoring to stop pulmonary hemorrhage. Conservative measures are confessedly ineffective. Their inadequacy and the gravity of this complication have made active surgical intervention seem justifiable. Before planning a surgical attack on hemorrhage it is necessary to determine its source. Specific studies in this regard are few; it is hoped that Dr. Wood's work may stimulate others who have access to autopsy material of large tuberculosis hospitals to more extensive investigation.

Tuberculous patients who bleed may be divided into several clinical categories; these divisions give some information as to the anatomic source of bleeding.

HEMORRHAGE FROM THE BRONCHIAL CIRCULATION ALONE

1. Bleeding may originate in ulcerative processes in the larger air passages. In children especially, but also in some adults, such hemorrhages may be accompanied by fever, often by high swinging temperature, constant barking cough, productive of small streaks of blood, sometimes of larger clots mixed with small amounts of pus and viscid tracheobronchial secretion. In children particles of necrotic material, at times larger pieces, may be expectorated; in adults, small chalky concretions. Such hemorrhages originate in caseous peritracheal and peribronchial lymph nodes which ulcerate through into the air passages. This bleeding arises from branches of the bronchial artery subserving these lymph nodes.

If ulceration and suppuration spread from the lymph node to the tracheobronchial wall, producing ulcerative perichondritis and extensive submucous ulceration with stenotic symptoms, the disease becomes serious. Aspiration of pus and blood may produce a true bronchiogenic

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caseous pneumonia. If the bronchial wall is but little involved, the disease may be comparatively innocent. Such patients are often subject to recurrent attacks of small hemorrhage, varying from small streaks to an ounce or two; bleeding may continue for a few days, may be accompanied by some fever, the patient may perhaps expectorate a small concretion or "lung-stone" and the attack be at an end. In the interval between attacks he may be perfectly free of symptoms.

Fatal hemorrhage has been described from this source, following erosion of one of the great vessels by a suppurating gland; usually the hemorrhage is scarcely serious enough to demand active treatment. Bronchoscopic application of iodoform powder and cauterization have been attempted in several such patients; more with the desire to influence ulceration and bronchial deformity than to stop hemorrhage. Results have not been encouraging, as indeed one would scarcely expect them to be.

Bettke described a mediastinal attack on these glands. This was carried out in one patient on account of stenotic symptoms rather than hemorrhage. The results were disappointing.

This category is distinguished clinically by recurrent short attacks of expectoration of bright red blood, usually in smaller amounts, occurring without ascertainable cause and followed by asymptomatic periods. It is mentioned here in order to separate it from the category of tuberculous patients in whom hemorrhage is of grave, often fatal import.

CAVITY HEMORRHAGE

This category includes patients whose constant purulent expectoration gives clinical evidence of ulcerative tuberculosis; who, usually, although not necessarily, have a lesion well enough localized to allow of its being strongly suspected as a source of their bleeding; in whom the localized lesion usually has the form of a cavity; who are often more or less constantly febrile and toxic; who are invariably so after they have begun to bleed; and who expectorate considerable amounts of blood, several ounces to a pint or more. Such patients often continue to bleed once they have begun, and die, either directly from loss of blood, or, more often, from a combination of loss of blood, acute aspiration pneumonia, and acute spread of their tuberculous disease. Active means should, therefore, be taken to stop hemorrhage of this category.

The source of hemorrhage is usually determinable. In these patients hemorrhage rarely ushers in the disease. They have usually been sick for a long time. Clinical records and x-rays that cast suspicion on a definite area as the bleeding one are often available. The patient himself may feel blood bubbling in one or the other side of his chest and may be able to localize the seat of hemorrhage. In bilateral or in hidden disease, bronchoscopy or new x-ray films may be necessary—a serious

difficulty in a patient who is bleeding alarmingly. Whatever diagnostic measures seem essential to localize the bleeding point should be carried out after preparations have been made for immediate operation, so that disturbance of the patient and possible aggravation of hemorrhage may be confined to an unavoidable minimum. Pneumothorax should be tried; unfortunately, it is not often possible to induce one in the old chronic, suppurative tuberculosis, from which patients of this category suffer.

If pneumothorax is impossible, other methods come into consideration. Several ways are open; decision is not easy, though stopping the hemorrhage is of paramount necessity. Operation is risky; the patients are anemic and toxic; anesthesia is difficult; any operation that interferes with cough and expectoration of aspirated blood courts disaster. One must consider the effect of whatever operation may be chosen on the underlying tuberculous disease.

Two ways are open—an indirect attack, which seeks to compress the bleeding cavity and put it at rest by any of the well-known methods—or an attack on the bleeding vessel itself. Exposure of the bleeding point with ligation or packing directly at the site of hemorrhage is ordinarily not feasible. Ligation in continuity at a site of election might be. If the source of tuberculous pulmonary hemorrhage lies in the pulmonary artery, in a Rasmussen's aneurysm or in a tuberculous erosion, ligation of a lobar branch at the hilum should stop the hemorrhage. The technique of ligature has been repeatedly described by Sauerbruch and his pupils, Schlaepfer, and others, who used it to produce shrinkage and fibrosis in various pulmonary disorders. If however, as Dr. Wood has stated, hemorrhage often arises not from the pulmonary but from the greater circulation, from branches of the bronchial artery, directly, or via dilated anastomoses, then ligation of the pulmonary vessels would be of no avail and a method would have to be employed by which the bronchial circulation would be interrupted. Dr. Wood's Case 10 from the Tuberculosis Service of the San Francisco Hospital is a case in point. Injection shows that the fatal cavity hemorrhage arose, in part at least, not from the pulmonary, but from the bronchial circulation, and that ligation of the pulmonary artery would have been insufficient (Wood's Fig. 10. Such bleeding could be controlled by putting a mass ligature around the lobar hilum, a ligature tight enough to interrupt both pulmonary and bronchial arteries, yet not so tight as to shut off the bronchus. Such a ligature is not difficult to apply; indeed, it is difficult to apply a ligature tight enough to occlude the cartilaginous bronchus unless one first crushes it. The objection will be made that such a ligature must of necessity lead to a necrosis and sloughing of the lobe to which it is applied. As a matter of fact it does not. The nutritional requirements of the pulmonary parenchyma are evidently very modest, as Dr. Wood's injections show. Enough blood reaches the lung via pleuritic adhesions to meet its nutritional needs. Whether in the

absence of adhesions enough blood would travel along the submucous vessels of the main lobar bronchus, which are not interrupted by the ligation described above, I do not know. The question may easily be solved by experiment.

The patient is prepared with sodium amytal and morphine. During operation evipal is administered slowly per vein. The thorax is entered under local anesthesia. In four patients exposure of the hilum was difficult and unsatisfactory on account of dense adhesions. Three pa-

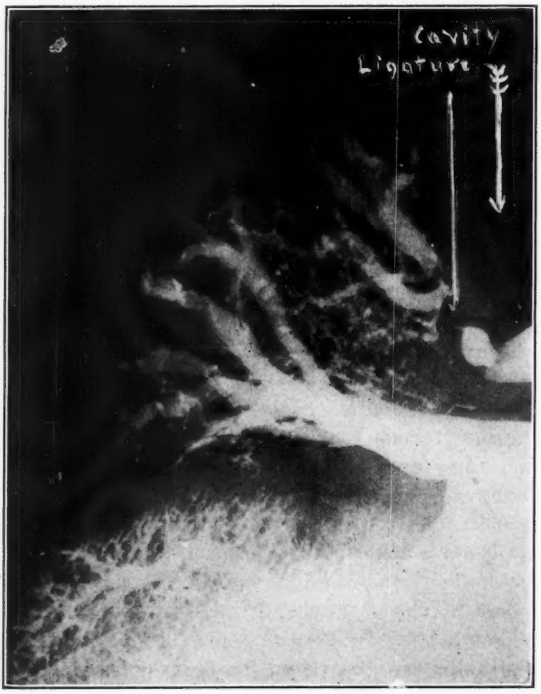

Fig. 1.—Case 1. Interruption of vessels by mass ligature around hilum of right upper lobe; back-filling through anastomosis traversing interlobar adhesions; control of cavity hemorrhage.

tients in whom massive ligature was tied about the hilum had a partial pneumothorax, which made it easy to surround the base of the lobe with a ligature. If the hilum cannot be reached and tied satisfactorily, the lobe may be collapsed by loosening it from its adhesions and by taking the pleura with it if necessary. It would be well to provide for sudden flooding of the trachea with blood expressed from a blood-soaked lobe by inserting an intratracheal catheter before opening the chest. This precaution was neglected in the patients of this series. There is reason to believe that one at least (Case 3) died because of it.

CASE 1.—(Dr. Wood's Case 11.) August K., a negro of fifty-two years, entered San Francisco Hospital Jan. 9, 1934, and died there Nov. 15, 1934. Pneumothorax was induced which collapsed the right base, but not the cavernous right upper lobe. The whole right upper lobe was converted into a large cavity with a fluid level. About November 1 the man began to bleed. On November 7 he lost about a quart of blood in twenty-four hours. A trap-door incision was made into the right upper chest. The right upper lobe was freed and a black silk ligature passed around the hilum, including the bronchus but not compressing it. The ligature stopped the hemorrhage, although following operation the patient continued to expectorate small amounts of old brown blood. The patient died on Nov. 15, 1934, of dyspnea and tuberculous toxemia. At autopsy there was found cavitation of his right upper lobe, but no gangrene or necrosis referable to the ligation. The spleen, the liver, the hilar and the cervical lymph nodes were tuberculous (Fig. 1).

Dr. Wood's Fig. 11 demonstrates the total interruption of the vessels of the right upper lobe by mass ligation at the hilum; it demonstrates the back-filling of the vessels distal to the point of ligature through anastomoses which traverse the interlobar fissure, and finally it demonstrates the fact that none of the various mixtures oozed through into the cavity, the hemorrhage from which had been controlled by the hilar ligature.

CASE 2.—T. D., aged fifty-six, entered the San Francisco Hospital on Oct. 1, 1931, and died there Oct. 14, 1931. He had been at the hospital in February, 1930, with hemoptysis and tuberculosis of his right upper lobe; he was transferred to the Hassler Health Farm on Dec. 5, 1930. On Sept. 28, 1931, he began to bleed again; he bled continuously up to four ounces a day. Pneumothorax was induced on Oct. 2, 1931; insufflation was continued up to Oct. 11, 1931. Bleeding decreased but did not stop. On Oct. 13, 1931, the chest was opened with a right upper trap-door incision. The lung was collapsed at the posterior portion of the chest. There were many adhesions, many of which were severed. An induration the size of a walnut, probably a cavity, was felt at the apex, which was held to the dome of the pleura by tight adhesions. Two catgut ligatures were passed around the apex proximal to the induration and tied tightly. The chest was closed. The pulse was rapid and respiration labored during the operation; the patient died the next day, apparently from circulatory failure. There was no further bleeding after operation. Autopsy was refused.

CASE 3.—R. E., a sixteen-year-old school boy, was admitted to the San Francisco Hospital on Oct. 22, 1936, and died there Oct. 25, 1936. He had had tuberculosis for two years, the course of which was characterized by hemorrhage, sometimes amounting to a cupful. Pneumothorax was tried but discontinued. Phrenectomy in February, 1936, brought some improvement. He entered San Francisco Hospital on October 22, bleeding considerably. Within a few hours of entry he expectorated seven ounces of bright blood. On October 23 the chest was opened by an anterior window. Many fine adhesions were separated down to the hilum of the left upper lobe, the lobe was compressed manually, causing a great quantity of blood to run into the trachea, whence it was removed by suction. The hilum of the left upper lobe was ligated with No. 2 chromic catgut ligatures, which compressed the vessels, the bronchus, and a part of lung tissue to a diameter of about 2 cm. A transfusion of 500 c.c. was given. The patient became gradually exhausted from difficult respiration and died on Oct. 25, 1936. Hemorrhage was apparently controlled. Death may have been due to aspiration of blood from the compressed lobe. Autopsy was refused.

CASE 4.—C. C., aged thirty-three years, entered the San Francisco Hospital on Sept. 4, 1931, with a history of cough and repeated hemorrhage since 1928. Bleeding apparently came from the right upper lobe, which showed fibrosis and several small

cavities, characteristic of tuberculosis. Countless sputum examinations had, however, failed to reveal acid-fast bacillus. She was discharged to the Arequipa Sanatorium on Sept. 23, 1931, operation being thought inadvisable.

She reentered Jan. 18, 1932, on account of sudden severe hemorrhage the day before. While in hospital she continued to bleed; on March 8, 1932, therefore, an anterior opening was made in the right upper chest, the hilum of the right upper lobe was isolated with considerable difficulty from its adhesions, the right upper lobe bronchus and the right upper lobe branch of the pulmonary artery were identified and the latter was isolated and tied.

The patient recovered with little trouble and was discharged on March 29, 1932. She bled no more until November, 1932. Her physician, Dr. Pierce of Hollywood, wrote in February, 1933, that she had had several hemorrhages in November and December of 1932. She has not been heard from since. Ligation of the pulmonary vessel alone was evidently insufficient to control hemorrhage. It may be assumed that part of the bleeding at any rate came from the bronchial circulation.

CASE 5.—J. McC., aged thirty years, entered St. Joseph's Hospital, San Francisco, on Oct. 2, 1929, and died there May 14, 1930. He had entered Weimar Sanatorium in August, 1929, for repeated hemorrhages. On arrival here he was found to have a large cavity in the right upper lobe with several smaller ones below. There was evidence of tuberculous involvement of the left apex also. Pneumothorax, phrenectomy, and a thoracoplasty in two stages not having stopped the bleeding, the chest was opened under gas anesthesia on May 2, 1930. Pleural adhesions were extremely thick and dense, especially the pericardiomediastinal ones, so that the hilum could not be safely isolated. An attempt was made, therefore, to separate the right upper lobe from the pleura, in the hope of compressing it. While doing this, a cavity lying posteriorly and laterally was entered, which held perhaps a half to one ounce. The cavity was smooth-walled, no vessel could be felt beating in it. It contained a few small old blood clots. Its bronchial connection seemed to be closed, and no air blew out from it. The man died May 14, 1930, two weeks after operation, probably of progress of the disease. Autopsy was refused.

CASE 6.—R. McC., aged twenty-eight years, was admitted to the San Francisco Hospital on May 1, 1936, and discharged May 6, 1937. His symptoms dated from July, 1935. About November, 1935, he began to have blood-streaked sputum. He had bilateral apical cavities, but bled from the left. Left pneumothorax was induced, and two months later a right pneumothorax. Soon after, he developed a spontaneous pneumothorax on the right. In spite of this bleeding continued. On Sept. 28, 1936, he lost a quart of blood. On this day the chest was opened by a trap-door incision. A large tense apical adhesion was tied and severed; further collapse was obtained by loosening the pleura and stripping it from the endothoracic fascia. Hereupon the lung collapsed and much blood was expressed into the bronchus, which was aspirated by suction and coughed out by the patient. The chest was closed. The next day the man expectorated two ounces of fresh blood, but has had no further bleeding. The sputum amounts to 25 c.c. per day and tubercle bacilli have not been demonstrated since February. The man was discharged to the country on May 6, 1937.

CASE 7.—B. B., aged sixteen years, entered San Francisco Hospital on Jan. 20, 1930, with bilateral pulmonary cavities. He began to bleed on Aug. 5, 1935. The bleeding increased so that on Aug. 8, 1935, the right chest was opened anteriorly. The right lung was small, about the size of two fists and contained scarcely any uninvolved parenchyma. It was everywhere adherent to the parietal pleura by dense hyperemic adhesions. The hilum was isolated and dissection carried upward, intending to free and remove the right upper lobe. However, it was seen that not only the upper but also the lower lobe bronchus of the much shrunken lung had been clamped,

so that the whole lung was removed. The bronchial stump was sutured with black silk, and the vessels tied. Respiration became more labored on the fourth day, although the patient was in an oxygen tent; the heart dilated and numerous râles were heard on the left side. The boy died suddenly on the morning of the fifth day after operation. Autopsy was refused.

Extrapleural attacks on pulmonary hemorrhage are not reported here. The results of these seven intrapleural operations have been discouraging. But two of the seven patients recovered. Three were treated by hilar ligature; all three died; two older men (aged 52 and 56), exhausted by prolonged disease and hemorrhage, died of circulatory failure; one young boy died probably of aspiration into the better lung. One patient with ligature of the pulmonary artery survived; her hemorrhages, however, recurred some seven months later. One cavity was opened and packed; this patient died two weeks later, probably of progression of the disease. One patient with bilateral involvement, who lost a quart of blood on the morning of operation, was treated by extensive open pneumolysis and bids fair to recover. One right sided, total pneumonectomy died on the fifth day after operation of circulatory failure.

It is not so much the technical features of these attempts at coping with desperate hemoptysis that seem of interest as the fact, brought out by Dr. Wood, that hemoptysis may have its source not only in the pulmonary, but in the bronchial circulation and that isolated ligation of the pulmonary artery, therefore, may not be sufficient. Case 4 would seem to support this contention. Mass ligation of the whole lobar hilum tight enough to occlude the vessels, but not the bronchus, is feasible, does not lead to gangrene or necrosis of a lobe (in the presence of pleuritic adhesions at least) and seems to check cavity hemorrhage. It may prove less dangerous not to stop with ligation, but to remove the lobe from which the hemorrhage comes.

SUMMARY

Pulmonary hemorrhage may originate in the bronchial circulation.

Patients with tracheobronchial lesions, especially ulcerating peribronchial and peritracheal lymph nodes may bleed from this source and form a clinically recognizable category.

The bronchial circulation may either directly or by way of anastomoses with the pulmonary circulation (which as Holman and Mathes, Wood, et. al., have shown are regularly dilated in pulmonary tuberculosis) contribute considerably to erosive hemorrhage in ulcerative cavernous phthisis.

Ligation of all of the structures of the hilum of a lobe, including the bronchial and pulmonary vessels but not occluding the bronchus, is technically feasible and will stop hemorrhage without causing necrosis of the lobe.

DISCUSSION ON "THE RÔLE OF THE DUAL PULMONARY CIRCULATION IN VARIOUS PATHOLOGIC CONDITIONS OF THE LUNGS," BY WOOD AND MILLER; AND "OBSERVATIONS ON SOURCES OF PULMONARY HEMORRHAGE AND ATTEMPTS AT ITS CONTROL," BY ELOESSER

DR. LEO ELOESSER, San Francisco, Calif.—I shall make my remarks very brief, because the work of Dr. Wood speaks for itself.

We have long suspected that bleeding takes place not only from the pulmonary arterial tree, but from the bronchial arterial tree, and that perhaps efforts to cope with hemoptysis will require taking cognizance of the facts as the slides shown by Dr. Wood demonstrate. In Dr. Wood's Case 10 an injection of the bronchial tree succeeded in producing an x-ray bleeding, as it were, into the cavity, and you will remember that a large clot of the opaque material oozed into the cavity.

With this in mind, we thought that efforts to cope with hemorrhage into pulmonary cavities by means of ligature of the pulmonary arteries would be futile, because even though the bleeding might occur originally from these vessels, yet anastomoses with the bronchial circulation were present in sufficient number to enable the pulmonary circulation to bleed, although the pulmonary arteries might be tied off. Such indeed was true in Case 4. I should like to show you one slide in which a ligature was thrown about the lobar hilum. I spoke of this to Dr. Alexander, who thought the lobe would necessarily become necrotic. Dr. Wood has shown that this is not true, that there is enough anastomosis through the pleura to enable the lobe to survive; although this man did ooze a little after the ligature was applied, hemorrhage stopped.

I have tried this in three instances. I undertook the operation only in exsanguinated patients; two of them died of spread of the disease; one, an older man, died of shock of the operation.

DR. EVARTS A. GRAHAM, St. Louis, Mo.—Will Dr. Eloesser kindly explain to us what he ligated in this last case? We are at a loss to understand.

DR. ELOESSER.—I ligated the whole hilum, Dr. Graham, thinking thereby I could ligate the pulmonary artery, the pulmonary vein, and the bronchial artery. This ligature was compressed to a degree to which everything was compressed except the bronchus. That is difficult to do, because it is easy to compress almost all the arteries without including the bronchus. Whether in such an instance there are enough anastomoses through the bronchial mucosa itself to enable this part of the lobe, which everybody would think naturally would die if such a ligature were passed about it, to survive or not, I am unable to say.

DR. GRAHAM.—Was the lung adherent to the chest wall?

DR. ELOESSER.—Yes, but the adhesions were rather fine, except in one particular point in which they were moderately dense. I do not know whether the return flow took place through the adhesions or through the interior of the bronchial lumen.

DR. E. J. O'BRIEN, Detroit, Mich.—A year ago I reported a series of lobectomies in which I tied four strands of catgut in the groove left in the stump after the proximal snare was removed and considerable apprehension was expressed as to the fate of the stump, many suggesting the possibility of it sloughing. No difficulty has as yet been encountered, and the stumps we have been able to examine showed no evidence of it, there being sufficient circulation for good healing, etc. The explanation probably lies in the dilatation of the bronchial arteries.

DR. D. A. WOOD, San Francisco, Calif. (closing).—There are just two things I should like to reiterate. First, I think the injection studies show that in tuberculosis there is a tremendous increase in the supply of oxygenated blood to the diseased parts; and second, any bleeding which occurs in a case of pulmonary neoplastic disease indicates to a certain degree that the tumor is primary and not metastatic neoplasm.

This noon we are going to set up an exhibit in a room upstairs showing typical examples of lesions produced experimentally in dogs by Drs. Holman, Reichert, and Mathes. Along with this exhibit will also be typical films from the injected human lungs.

DR. LEO ELOESSER, San Francisco, Calif. (closing).—I should like to call attention to the fact that at Stanford a number of people have been interested in this work. It is not necessary for me to call to your attention the work of Dr. Holman and Dr. Mathes, who made similar experiments, and whose films Dr. Wood will show. The last fact that he brought out is in itself, I think, quite important enough to justify this presentation, namely, the fact that if a pulmonary neoplasm bleeds, it is likely to be a primary, and if it does not bleed, it is a metastasis. That is a clinical fact that is quite worthy of attention.

The American Association for Thoracic Surgery

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The American Association for Thoracic Surgery

The twenty-first annual meeting of the American Association for Thoracic Surgery was held in Atlanta, Ga., April 4, 5, and 6.

Honorary membership was conferred upon Dr. Chevalier Jackson of Philadelphia in recognition of his outstanding contributions to the subject of thoracic disease.

Dr. Harold Brunn of San Francisco was elected to the Presidency; Dr. A. V. S. Lambert of New York was elected to the Vice-Presidency; Dr. I. A. Bigger of Richmond, Va. was elected Treasurer; Dr. Richard H. Meade, Jr. was re-elected Secretary; and Dr. Evarts A. Graham was re-elected Editor. To the Council were elected Dr. Frank S. Dolley of Los Angeles and the retiring President, Dr. Stuart W. Harrington of Rochester, Minn.

An amendment to the By-Laws, Art. IV, Sec. 3, was passed, changing the wording from: "Associate Membership shall be limited to seventy-five" to read, "Associate Membership shall be limited to 100."

The following changes in membership status were voted:

Resignations:

Dr. Charles Gordon Heyd, New York City, N. Y.
Dr. James F. Mitchell, Washington, D. C.

Honorary Membership:

Dr. Chevalier Jackson, Sr., Philadelphia, Pa.

Active Members retired to Senior Membership:

Dr. Abraham O. Wilensky, New York, N. Y.
Dr. John D. Kernan, New York, N. Y.
Dr. R. G. Ferguson, Fort San, Saskatchewan, Canada
Dr. Frederick T. Lord, Boston, Mass.
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Associate Members elected to Active Membership:

Dr. L. Wallace Frank, Louisville, Ky.
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Dr. Everett Drash, Charlottesville, Va.
Dr. Robert Janes, Toronto, Ont., Canada
Dr. Donald King, Boston, Mass.
Dr. Herman Moersch, Rochester, Minn.
Dr. Joseph Weinberg, Omaha, Neb.
Dr. Max Pinner, Ithaca, N. Y.

Associate Members re-elected to Associate Membership:

Dr. George F. Herben, Yonkers, N. Y.
Dr. Foster Murray, Brooklyn, N. Y.
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Candidates elected to Associate Membership:

Dr. W. E. Burnett, Philadelphia, Pa.
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Dr. Richard Davison, Chicago, Ill.
Dr. Plimpton Guptell, Rochester, N. Y.
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Dr. M. Dawson Tyson, Hanover, N. H.
Dr. Mark H. Williams, Binghamton, N. Y.

Los Angeles was chosen as the place of the next meeting; the dates will be announced later, but in all probability the meeting will be held in June, 1939.

Book Review

THE LARYNX AND ITS DISEASES. By C. Jackson and C. L. Jackson. Philadelphia, 1937, W. B. Saunders Company. 555 pages.

This is an interesting departure from the usual style of textbook writing in that it deals only with the larynx. It describes vividly and in detail the normal and pathologic anatomy with profuse and beautiful illustrations, not only of the normal larynx but also of a wide variety of diseases of the larynx. Diagnostic methods of the past and present are presented with special emphasis on the value of direct inspection of the larynx of the very young as well as older patients. The point is well taken that all laryngologists should be able to do direct laryngoscopy, and that it should be practiced more regularly than is now done. All the usual disorders as well as the unusual (in a surprising number) are described in great detail. The important subject of the indications for tracheotomy, the various types of tracheotomy, and the aftercare of these cases are most carefully described. The means of establishing a diagnosis and differentiating between the more serious laryngeal diseases, such as syphilis, tuberculosis, cancer, etc., are described at length. Treatments of all of these and other laryngeal diseases, serious and less serious, are described in detail from the medical, surgical and radiologic standpoint. Surgical technique and aftercare are described in great detail and profusely illustrated. This important text covers the entire field of diseases of the larynx in a most comprehensive manner.

M. F. Arbuckle.

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